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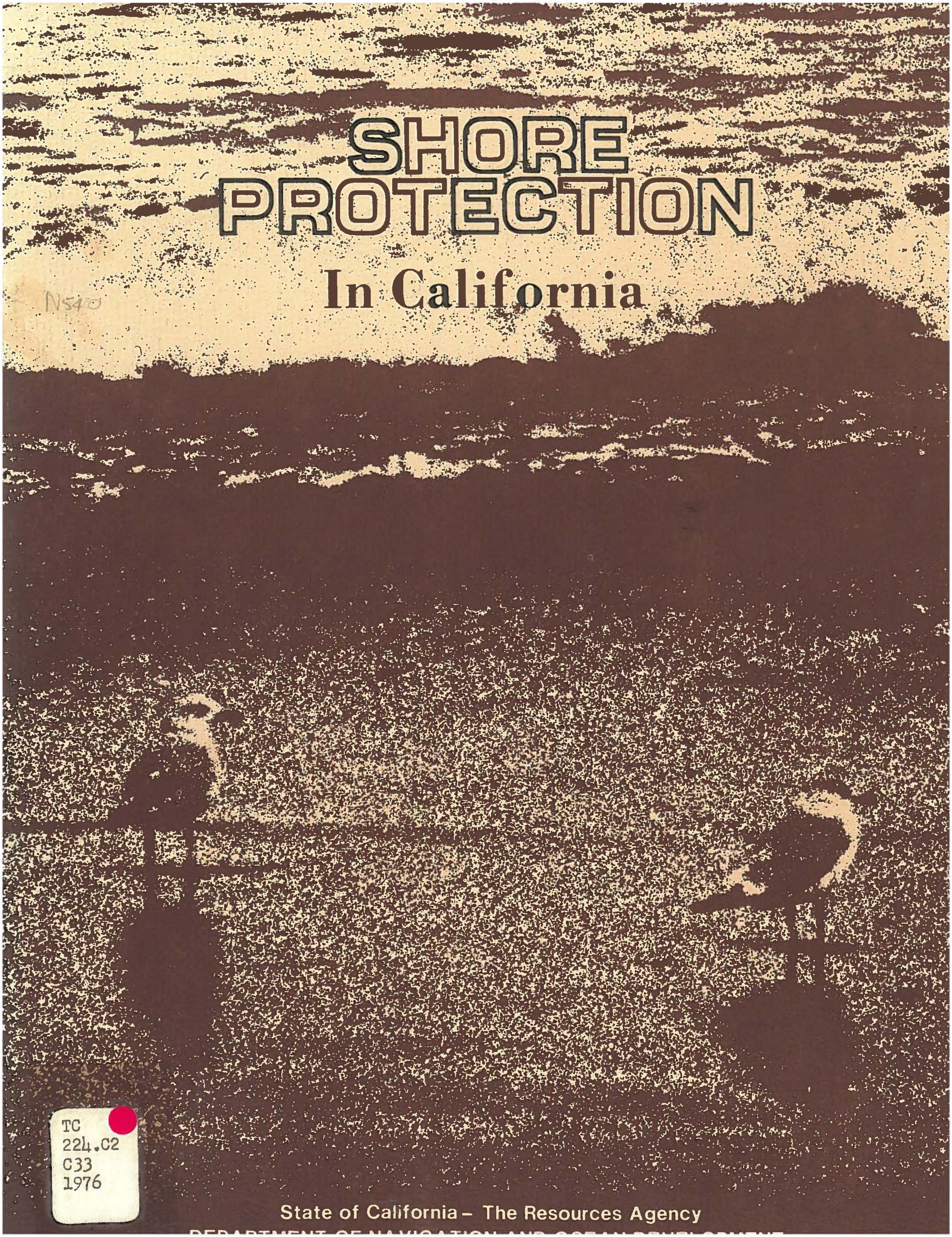
Shore Protection in California

Department of Navigation and Ocean Development



SHORE PROTECTION

In California

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State of California – The Resources Agency

DEPARTMENT OF NAVIGATION AND OCEAN DEVELOPMENT

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SHORE PROTECTION

In California

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April 1976

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF NAVIGATION AND OCEAN DEVELOPMENT

Foreword

In excess of 1,500 miles or 85 percent of the 1,810 miles of California's shoreline is subject to erosion. Storm waves from across the Pacific Ocean as well as those locally generated carve and shape the coastline. The natural erosion process has been accelerated by flood control measures that prevent the transport of sand to sustain protective beaches. Man-made structures along the shore have changed the waves and currents to create new erosion problems. Increased use of the coastline as well as erosion is threatening this limited resource.

A public understanding of the shoreline erosion problems and how to solve them will help to conserve and protect this important asset. The Department of Navigation and Ocean Development has prepared this report to further that purpose. It contains a brief description of the forces of nature that form the beaches and erode the bluffs, the effect man has had on the process, and the means available for corrective action.

The Department of Navigation and Ocean Development is the state agency responsible for protecting the California shoreline against erosion. In cooperation with the federal and local government, it monitors the changes that occur. It is searching for new solutions through research at the universities and participation in other cooperative programs.State funds are made available on a matching basis for the construction of qualified projects.

The department can assist local agencies by providing information and guidance on shoreline protection. We encourage your questions, comments, and suggestions.

Marty Mercado

MARTY MERCADO
Director

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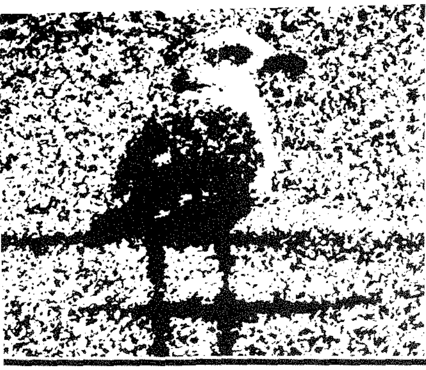


Introduction

The State of California has about 1,072 miles of shoreline facing the Pacific Ocean and 275 miles of shoreline on the offshore islands which is comprised of wide, sandy beaches, scenic bluff areas, and rocky headlands that meet the sea. This shoreline environment provides opportunities for a variety of uses including: recreational activities, homesites, industrial complexes, and commercial and small craft harbors; their value totaling billions of dollars. Southern California's sandy, gently sloping beaches extending almost continuously from Santa Barbara to the Mexican Border attract millions of people each year not only from the nearby population centers, but from all over the world. The more northerly shorelines, while not endowed with a year-round warm climate, offer a variety of scenic beauty ranging from rugged rocky headlands to great expanses of dune-backed beaches.

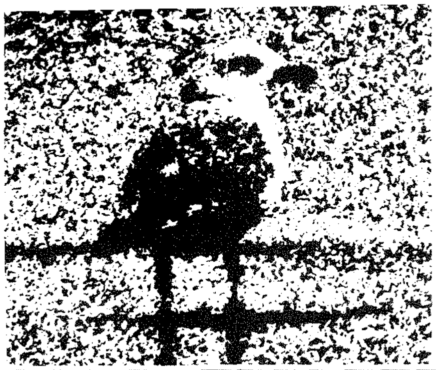
The California Department of Parks and Recreation has approximately 70 State beach parks scattered throughout the 15 coastal counties. These state beaches occupy more than 100 miles of shoreline and more than 8,300 acres. In addition, there are many city and county beach developments which, when added to the State beach parks, provide a substantial economic base for recreation use of California's shoreline.

Wave forces acting on the shoreline keep in motion billions of yards of sand along the coast. The magnitude and direction of movement are functions of many complex factors, so that some sections of the coast are eroding while others are accreting. Beach areas in excess of 100 feet in width have been known to erode away during a single storm. Cliffs have been found to recede at rates of up to three feet per year.

In open, undeveloped shoreline areas, erosion may be unnoticed for many years because there may be few visual reference points with which to measure. However, in areas where man has built along the shoreline to the water's edge, his works may be threatened by damage from wave action that is constantly reshaping the shore.

Recognizing that the shoreline is a valuable resource and everyone's concern, state and federal programs have been created by the various Legislatures to combat beach erosion and develop shoreline protection and enhancement programs.

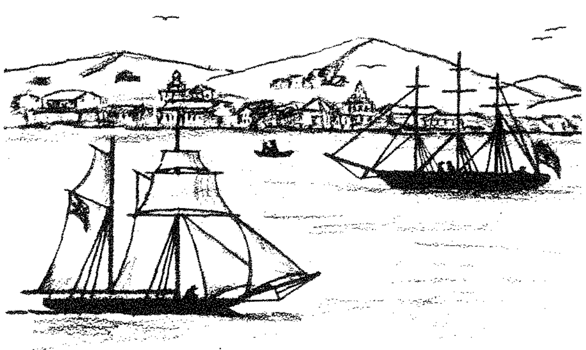

MERRILY ANN



Man's Intrusion on the Shore

The shoreline, the meeting of air, sea and land have played an important role in making California what it is today. The Spanish explorers used the sheltered bays as stopping places on their trips to the Orient; the early Mexican ranchers loaded hides from the bluffs; Drake used the shores near San Francisco to repair his vessels, and the Russians harvested the furs from the animals that inhabited it.

The Gold Rush of 1849 brought a new era. Timber was needed to build new cities, industry and farm buildings. Lumber schooners were loaded at every indentation along the Northern California coast that offered some protection. Ships and barges were constructed along the shore to transport the lumber and produce from outlying areas.



The immigrants to the Golden State settled next to the ocean for they found the climate near the coast pleasant, the transportation to the East Coast more convenient, the coastal valleys rich and fertile. Gradually some of the coastal developments became obsolete and others grew into great port complexes such as San Francisco, Los Angeles and San Diego. Some remained in the form of fishing harbors and others as small resort communities.

As the State grew and prospered, a great new western migration took place. The nation's population was attracted by California climate, a prosperous growing economy and the excitement of the West.

The nation's affluence brought mobility and leisure time. Beach resort areas flourished, second homes sprang up side by side along the beach and ocean view subdivisions were perched on the bluffs above the pounding surf. More and more people descended upon the shoreline to sunbathe, swim, surf and sail their boats.

New harbors were built, some to meet the crisis of World War II and others to protect the growing recreational fleets. In many instances, these harbor structures interrupted the longshore movement of sand and starved adjacent downdrift beaches.

The rivers were dammed to provide the expanding population and industry with flood control protection, water supply and hydroelectric power. These dams have deprived large parts of the coast the supply of sand previously available.

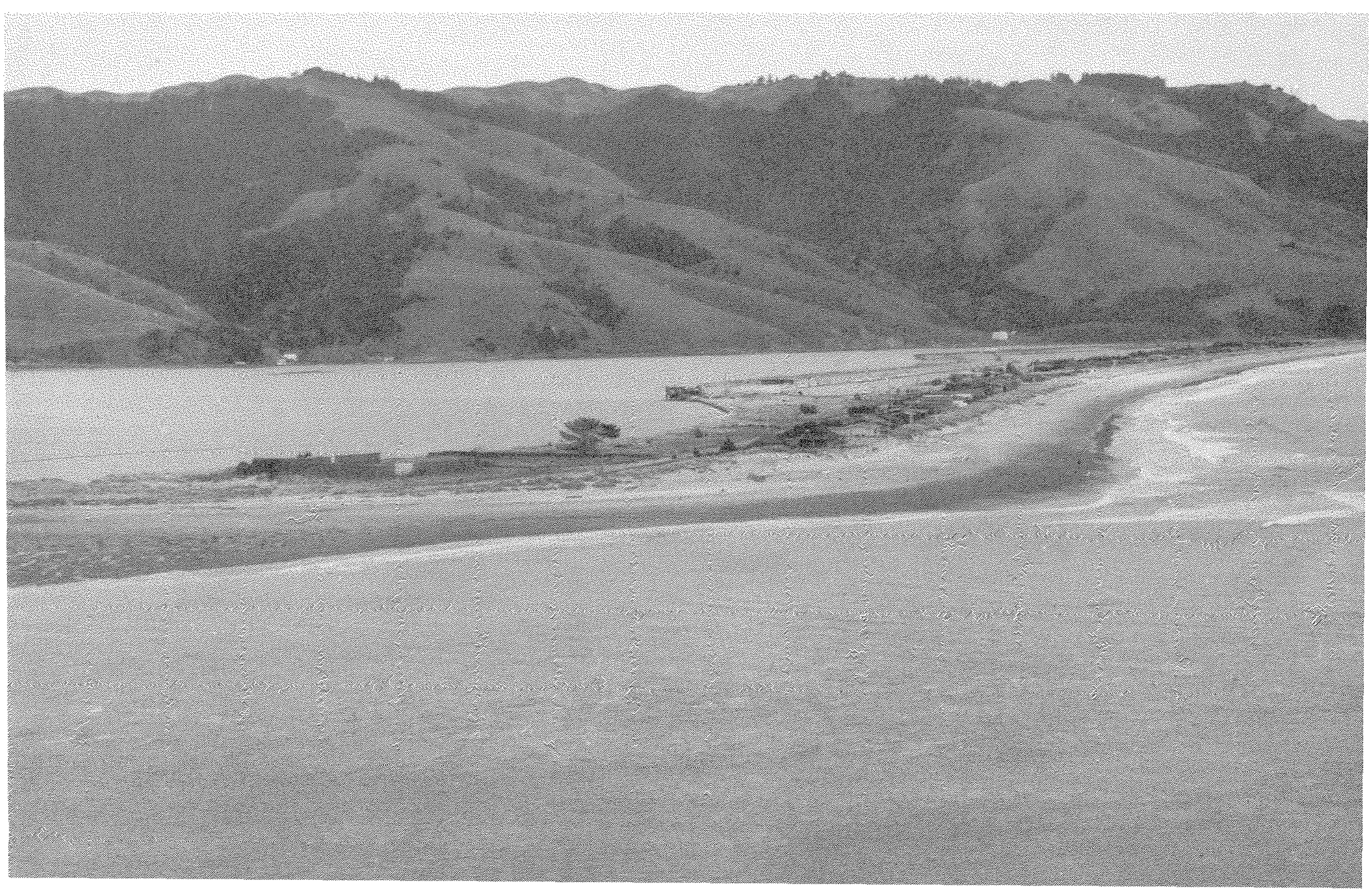
The ocean, however, continued relentlessly to send its waves to the shoreline, eroding the deltas that intruded into its domain, eroding the unconsolidated bluffs that had been raised by teutonic forces beneath earth, shifting the sand on the beaches to suit the storm climate and in general continued to reshape the shoreline as it had done since the beginning.

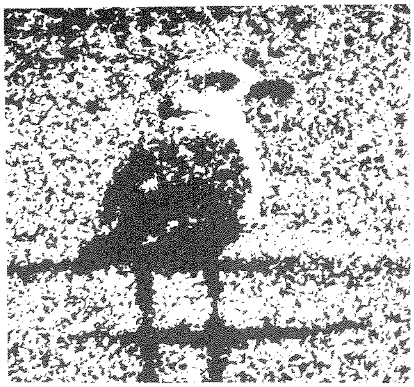
About 85% of California's shoreline is subject to some degree of erosion. Only on those sections where man has developed facilities to satisfy his needs has he become noticeably aware of this fact.

Regions of the coast that have accreted and eroded with climatic cycles, particularly in delta areas that build up during periods of heavy river flows and erode during periods of droughts, are especially susceptible to man's encroachment for these areas normally have excellent sandy beaches and broad flat areas that are easily turned into streets and building sites. Cliffs and bluffs which have been sculptured by wave action are desired for the view of the ocean and the ever changing wave patterns, but these very waves which attract man's interest are also eroding the bluffs, turning the choice view lots into beach sand and giving the second tier of lots the opportunity to be next to the ocean.

Some 700 miles of the 1100 miles of California coastline facing the ocean is backed by cliffs or bluffs. If these are protected by a beach which remains intact during a severe storm and prevent the waves from eroding their base, or if the cliffs themselves are made of hard durable rock, the ocean is unable to encroach upon the land. If, on the other hand, there is virtually no protective beach and the cliff material breaks down easily, bluffs will be undercut and landslides will result. The material lost to the cliffs will be broken down by the surf and added to the beach.

About 150 miles of California's shoreline is backed by dunes. Inasmuch as the dunes are formed by sand blown from the beach beyond the normal reach of the waves, they become a second line of defense against the encroachment by the sea. They may erode during a severe storm but they rebuild with time to offer protection against future wave action. Removal of the dunes for any purposes exposes the land areas behind to severe damage.





Natural Beach Protection

The beaches of California, which have a high value as a natural resource, and are limited in extent, are being destroyed through erosion. Some of this loss is from natural causes but much of it is associated with man-made developments.

Where the land meets the ocean, nature has provided the shore with a natural defense against the attack of the waves. The first defense against the waves is the sloping nearshore bottom on which the long period waves with the greatest energy break and dissipate most of their energy. Yet some waves continue toward the shore with force and energy still at tremendous levels until they reach the beach. There they break and unleash most of their destructive energy. This process of breaking often builds in front of the beach another defense in the form of an offshore bar which helps to trip following waves. The long period broken waves reform to break again and may do this several times more before finally rushing up on to the beach. At the top of wave uprush a ridge of sand is formed and serves as a defense against uprush of following waves. Beyond this ridge, or crest of the berm, lies the flat beach berm which is reached only by higher storm waves.

Along the Atlantic and Gulf Coast the mainland is protected by barrier beaches that are essentially long narrow islands or sand spits built parallel to the shoreline by wave action and changes in sea level. Not so in California where the entire coast is exposed to those storms generated in the North Pacific Ocean in the winter or those generated in the South Pacific Ocean in the summer. Only a few estuaries or lagoons have the protection of a barrier beach to set them apart from the ocean (lagoons, in North Humboldt, Del Norte County, Bodega, Tomales Bay, Bolinas Lagoon, a few in Monterey Bay and those in San Diego County). The offshore islands provide a wave shadow to the Southern California coastline but the shadow shifts with the wave direction so that each section of coast is fully exposed to waves from a number of quarters. Only the shores of the natural bays (Humboldt, San Francisco and San Diego) or those made by man (Los Angeles-Long Beach) are protected from the onslaught of Pacific storms.

If a great deal of sand is exposed on the beach, winds blowing inland over the foreshore and berm move sand behind the beach to form dunes.

Grass, and sometimes bushes and trees, grow on the dunes, and the dunes become a natural levee against the sea attack. Dunes are the final protection line against the sea, and are also a savings bank for the storage of sand against a stormy day.

And stormy days do occur. Strong winds blow high waves before them. These waves are so huge that the nearshore slope weakens them only slightly. The thrust of the wind and the waves toward shore raises the elevation of the sea and large waves pass over an offshore bar without breaking. If the storm occurs at high tide, the storm surge and the tide superelevate the waves and some of them may break high on the beach or even at the base of the dunes. After a storm or stormy season, the natural defenses are again reformed by normal wave and wind action.

Origin and Movement of Beach Sands

The sands of the beaches and nearshore slopes are small resistant rock particles that have been carried to the oceans from eroding uplands. Some sand particles have traveled many miles from inland mountains. Other sand is derived from erosion along the shore. When the sand reaches the shore, it is moved alongshore by waves and littoral currents (currents adjacent to the shore). This transport by littoral currents is a constant process and moves great volumes of sand alongshore. In most places this movement changes direction as the direction of wave attack changes.

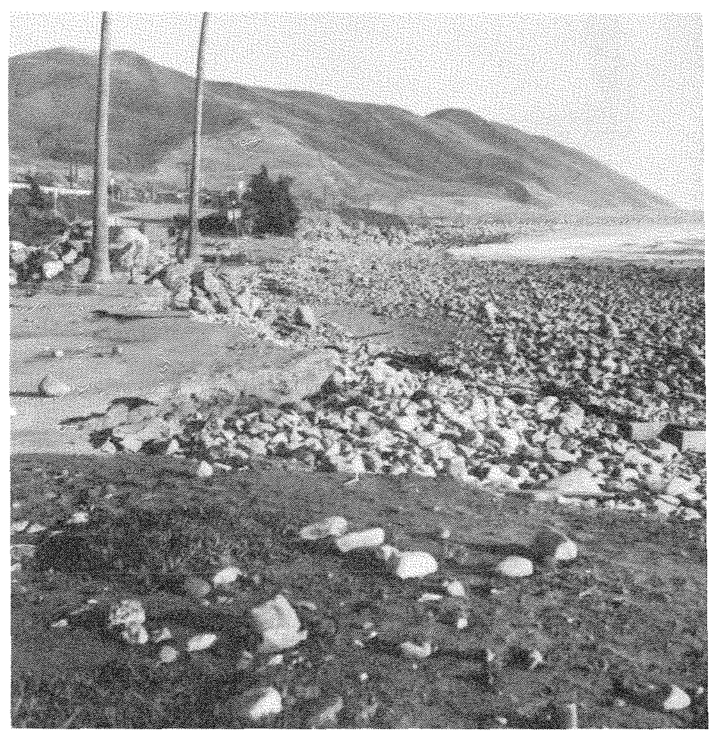
The natural defenses of the land against the sea, the erosion by storm waves, and the littoral transport of the sand have shaped and reshaped the sandy beaches for millions of years.

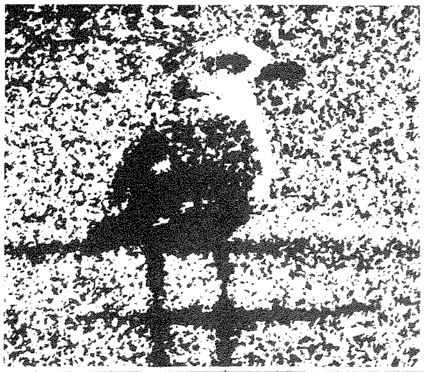
Today's Beach Conditions

Today, we find that although California has been blessed with many beautiful beaches for outdoor enjoyment, in most areas there is less and less sand reaching them and they erode. Causes for our shrinking beaches are in general the normal geologic changes and those made by man. Changes which occur on a short-term basis, and which become more urgent, may be caused by climatic patterns such as a series of years of heavy flooding or droughts. Also, increased storm activity such as tropical hurricanes or even a tsunami caused by some violent geological action in the North Pacific Ocean will cause short-term changes.

Changes caused by man may cause a striking adverse effect. An example of this was the denuding of 12 miles of sandy beach following the construction of the breakwater at Santa Barbara that trapped the sand moving along the coast. Some changes may be more subtle. The development of urban areas with thick lawns and paved areas prevent heavy rains from eroding the hillside to make sand for the beaches. Man may even cause erosion by his attempts to prevent it. Stabilizing an eroding bluff eliminates it as a sand supplying source.

Flood control and water supply dams are necessary to the everyday life and safety of people, yet these dams alter the flow of water which brings sand from inland to the shores. Unless means are provided to overcome these losses of beach sand from the shore zone, or methods are devised to reduce the effects of development, stabilizing beaches will become an ever-increasing problem.





Forces of the Sea

Waves

The familiar waves of the sea are "wind waves" generated by the winds blowing over the water. They may vary in size from ripples on a pond to giant waves in the oceans as high as 100 feet. Wind waves cause most of the damage to our seacoasts. Another type of wave, the tsunami, is created by earthquakes or other large disturbances on the ocean bottom. Tsunamis fortunately do not occur frequently but their effect can be disastrous.

If winds of a local storm blow toward the coast, the generated waves will reach the local beach in essentially the form in which they are generated. Under these conditions, the waves are rather steep, that is, the wave length is only from 7 to 20 times the wave height. If the waves are generated by a distant storm, they may travel through hundreds or even thousands of miles of calm areas before reaching the shore. Under these conditions the waves "decay" -- the short, steep waves are eliminated, and only relatively long, low waves reach the shore. Such waves have lengths from 30 to 500 or more times the wave height and are called "swells" or "ground swells".

Tides and Winds

The forces of the sea originate in the sun and the moon. The sun causes air movements or winds, and helps the moon create the tidal rise and fall of the ocean surface.

Air movements originate with temperature changes. The sun heats the earth, the waters of the earth, and the air around the earth, but this heating is not uniform. The air in some parts of the earth is heated more than that in other places. The warmer, lighter air rises, causing a zone of reduced pressure; winds result as colder, denser air moves into this zone.

The moon, and to a lesser extent the sun, creates the tides of the sea. Together they generate the tides because they attract the water masses of the earth in the same way that the earth attracts objects near its surface. Because of this gravitational force of attraction and the fact that the sun, moon, and earth are always in motion with relation to each other, the waters of the ocean basins are set in motion. Once the water masses of the oceans have been set in motion, they create the tides. The tidal motions of the water masses are a form of wave motion.

Wind waves are of the type known as oscillatory waves, and are usually defined by their height, length, and period. Wave height is the vertical distance from the top of the crest to the bottom of the trough between crests. Wave length is the horizontal distance between successive crests. Wave period is the time between successive crests passing a given point.

When waves move over the water, only the form and energy of the waves move forward. Advance of the wave form causes oscillatory motions of the individual water particles.

These particles describe circular orbits in deep water with each particle returning to its original position after passage of the wave. The diameters of the circles decrease with depth from a diameter at the surface equal to the wave height. In shallow water the orbital movements become flattened, and at the bottom are merely horizontal oscillations to and fro as the wave form passes.

The height, length, and period of wind waves are determined by the fetch (the distance the wind blows over the sea in generating the waves), the speed of the wind, and the length of time that the wind blows. Generally, the longer the fetch, the stronger the wind, and the longer the time that the wind blows over the water, the larger the the waves will be. The wind generates waves of many heights, lengths, and periods simultaneously as it blows over the sea.

Currents and Surges

Currents are created in oceans and adjacent bays and lagoons when the water in one area becomes higher than the water in another area. The water in the higher area flows toward the lower area, creating a current. Some causes of differences in the elevation of the water in the oceans are the ordinary tides, the blowing wind, waves breaking on a beach, and streams which flow into the ocean.

The wind creates currents because, as it blows over the surface of the water, it creates a "stress" on the surface water particles, and starts these particles moving in the direction in which the wind is blowing. Thus, a surface current is created. When such a current comes to a barrier, such as a coastline, the water tends to pile up against the land. In this way "wind tides" or "storm surges" are created by the wind. The amount of "storm surge" depends on the wind velocity and direction, the fetch, and the water depth. Storm surges may also be increased by the funneling effect in converging estuaries.

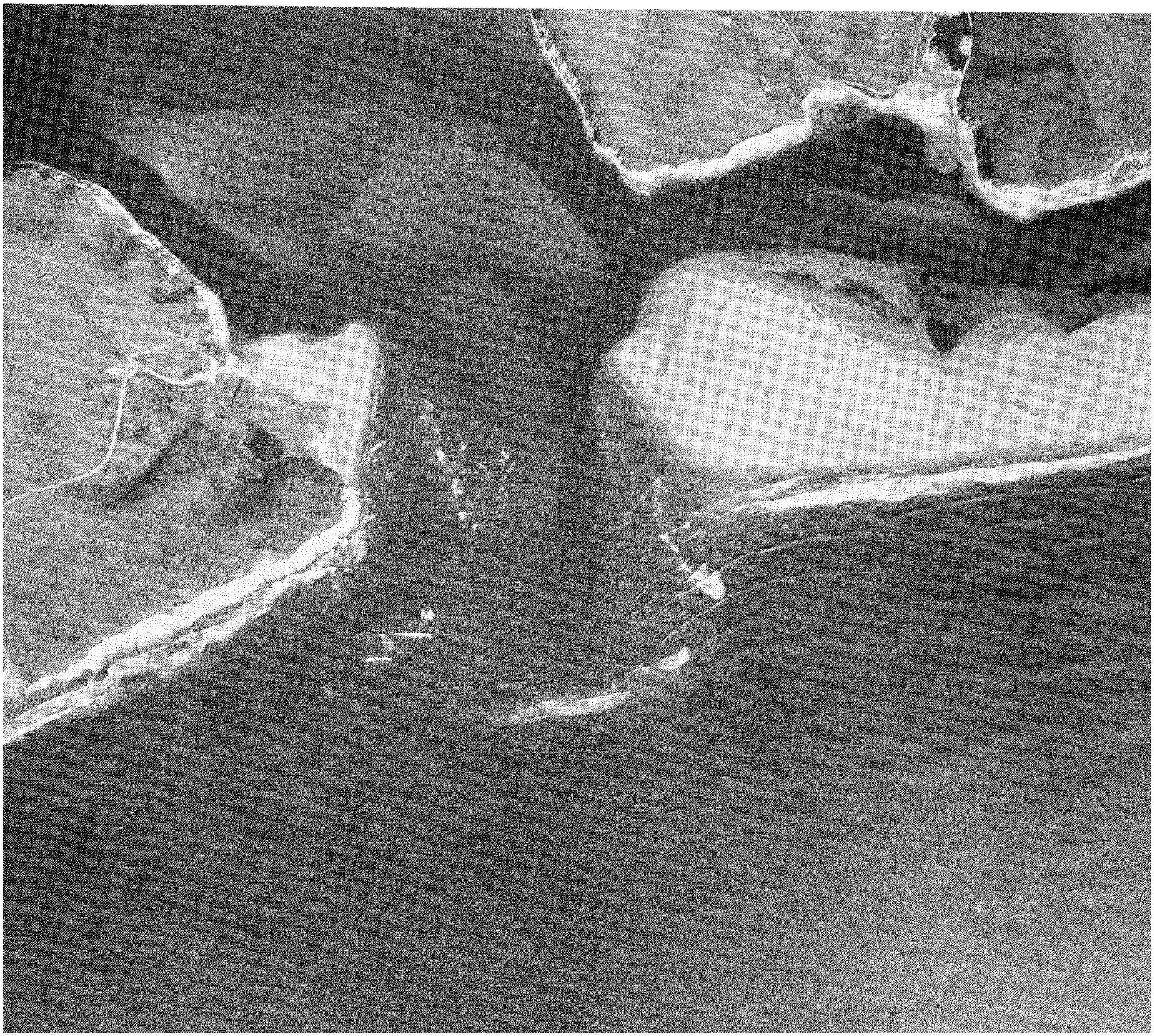
Waves create a current known as the "longshore current" when they approach the beach at an angle. As they break on the beach, they set up a current which moves parallel to the shore in shallow water. The longshore current is frequently noticeable to swimmers and bathers in the surf when they find themselves being moved slowly along the beach. This current, under certain conditions, may turn and run out to sea in what is known as a "rip current". Rip currents sometimes are referred to by bathers as "undertow", and when strong enough they may endanger swimmers by carrying them seaward to deeper water rather unexpectedly.

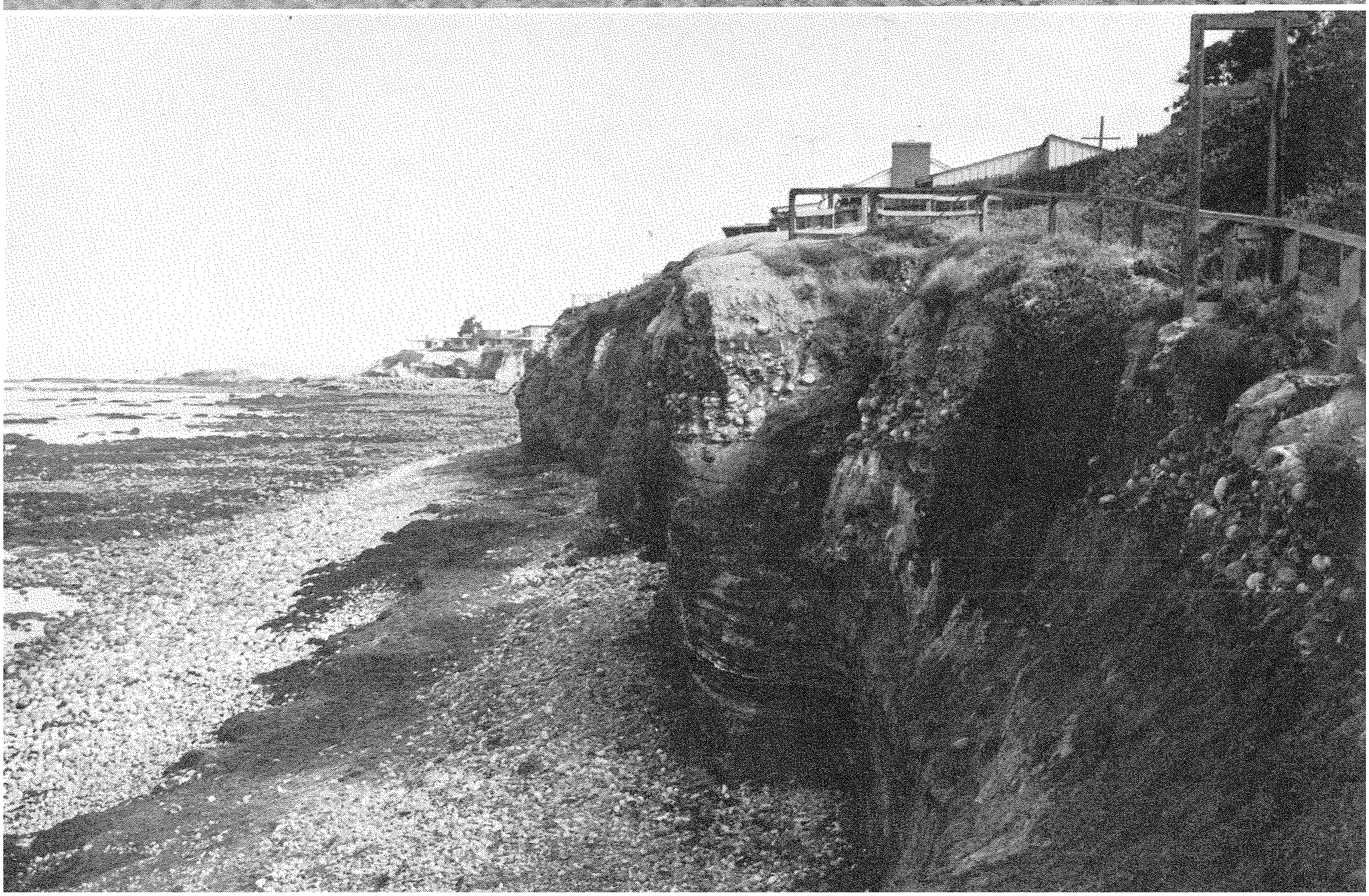
The rivers and streams which flow into the ocean are currents themselves, and they carry the sediments which have been eroded from the land.

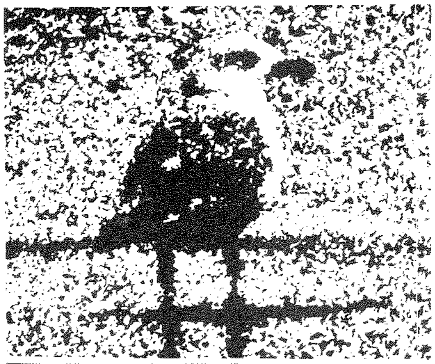
Tidal Currents

The tides are a rise and fall in the water level. If the water level is to rise and fall at any particular place, then water must flow into and out of the area. The most important currents that the tides generate are those at inlets to lagoons and bays or at entrances to harbors. At most such places the water flows in when the tide in the sea is rising (flood tide) and then flows out as the tide in the sea falls (ebb tide).

In addition to creating currents, the tides are constantly changing the level at which the waves attack the beach. The mean range of the tide along the coast varies from 3.7 feet at San Diego to 5.1 feet at Crescent City. Tides within bays and estuaries may be less or more than these ranges depending upon their size and shape.







The Behavior of Beaches

Beach Composition

The sediments of a beach are determined by the forces to which the beach is exposed and the type of material available at the shore. Most beaches are composed of very fine to very coarse sand. This sand is supplied to the beaches by the streams, and by the erosion of the shores by waves and currents. Mud does not usually remain on beaches because waves create much turbulence in the water along the shore and the fine materials which compose muds are kept in suspension in the shore area. It is only after moving away from the beaches into quieter or deeper water that these fine particles settle out and deposit on the bottom. A few beaches in California are composed of rather large stones, frequently called ''shingle'' or ''gravel''. Some beaches on water bodies where wave action is very mild are composed of mud. If grasses grow in the mud, the shores are considered to be marshland.

Beach Characteristics

The characteristics of a beach are usually described in terms of the average size of the sand particles that make up the beach, the range and distribution of sizes of those particles, the elevation and width of berm, the slope or steepness of the foreshore, and the general slope of the inshore zone fronting the beach. Generally, the larger the sand particles which make up the beach, the steeper the beach will be. Beaches with gently sloping foreshores and inshore zones usually have a preponderance of the finer or smaller sizes of sand.

Breakers

The primary agent causing onshore, offshore, and alongshore movement of sand is the breaking wave or ''breaker''. As a wave moves into shallower water near the shore, the distance between crests becomes shorter and the wave height increases until it finally reaches a depth of water which is so shallow that the wave collapses, or ''breaks''. This depth is equal to about 1.3 times the wave height. Thus, a wave 3 feet high will break in a depth of about 4 feet. Breaking results in a sudden dissipation of the energy of the wave, which causes a great turbulence in the water, and stirs up the bottom materials. After breaking, the water travels forward as a foaming, turbulent mass, expending its remaining energy in a rush up the beach slope, then falling under the influence of the force of gravity, the water runs back down the beach slope to the sea.

Effects of Wind Waves

Wind waves affect the beaches in two major ways. Short steep waves, which usually occur during a storm near the coast, tend to temporarily tear the beach down and form the offshore bar. However, when the local weather is fair, the long swell which comes ashore from distant storms tends to move the bar material back and rebuild the beaches. On most beaches, there is a constant change caused by the tearing away of the beach by local storms followed by gradual rebuilding by swells from distant storms. A series of violent local storms in a short time can result in severe erosion of the shore, if there is not enough time between them for swells to rebuild the beaches. Alternate erosion and accretion of beaches is seasonal on some beaches; the winter storms tear the beach away, and the summer swells rebuild it. Beaches may also follow long term cyclic patterns. They may erode for several years, and then accrete for several years.

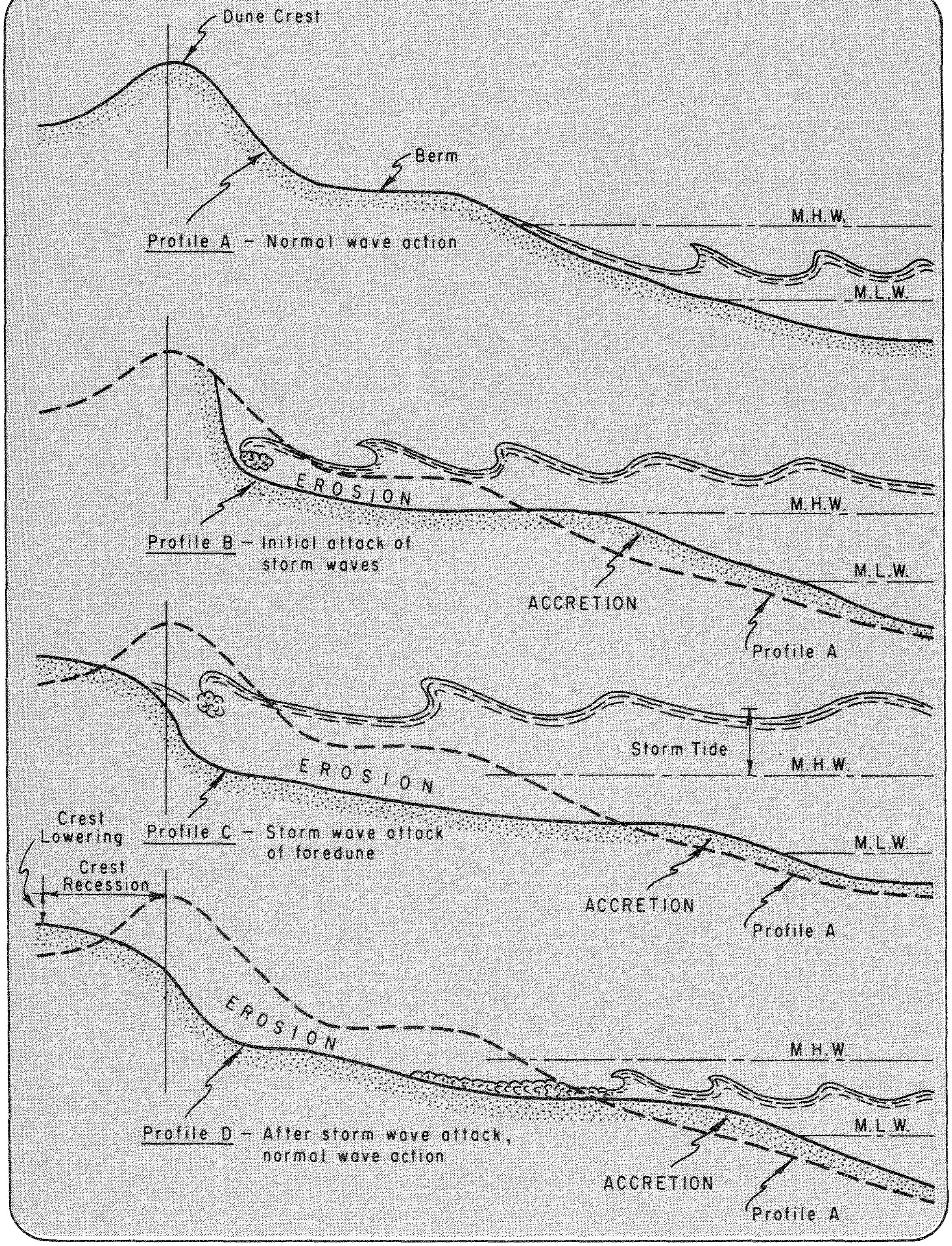

Dune Crest
Berm
M.H.W.
Profile A - Normal wave action
M.L.W.
EROSION
M.H.W.
Profile B - Initial attack of storm waves
M.L.W.
ACCRETION
Profile A
Storm Tide
M.H.W.
EROSION
Crest Lowering
Profile C - Storm wave attack of foredune
M.L.W.
Crest Recession
ACCRETION
Profile A
EROSION
M.H.W.
M.L.W.
Profile D - After storm wave attack, normal wave action
ACCRETION
Profile A

Figure 1

Littoral Transport

The longshore current is very important in coastal processes because it carries sand which has been stirred into suspension by the turbulence of the breaking waves. The sand moved in this way is known as "littoral drift". Onshore and offshore sand movements are caused by low swells and steep waves respectively, and coupled with littoral drift help explain the major shoreline changes on the open coasts of the world. This onshore-offshore process associated with storm wave events is illustrated in Figure 1, while Figure 2 illustrates an onshore-offshore path for motion of sand particles associated with each individual wave.

The direction and violence of the wave attack determine the direction and magnitude of the littoral transport at a given time. For instance, on a coast facing to the west, violent storm waves from the northwest would produce a high rate of littoral transport toward the south. Conversely, mild wave action out of the southwest would result in a much smaller rate of littoral transport to the north. However, if the southwest waves existed for a much longer time than did the northwest waves, the effect of the southwest waves might well be more important in moving sand than that of the northwest waves. In reality, most shores show changes in the direction of littoral transport as the weather patterns change. However, most shores consistently have a net annual littoral transport in one direction. Determining the direction and the average net annual amount of the littoral drift is important in developing shore protection plans.

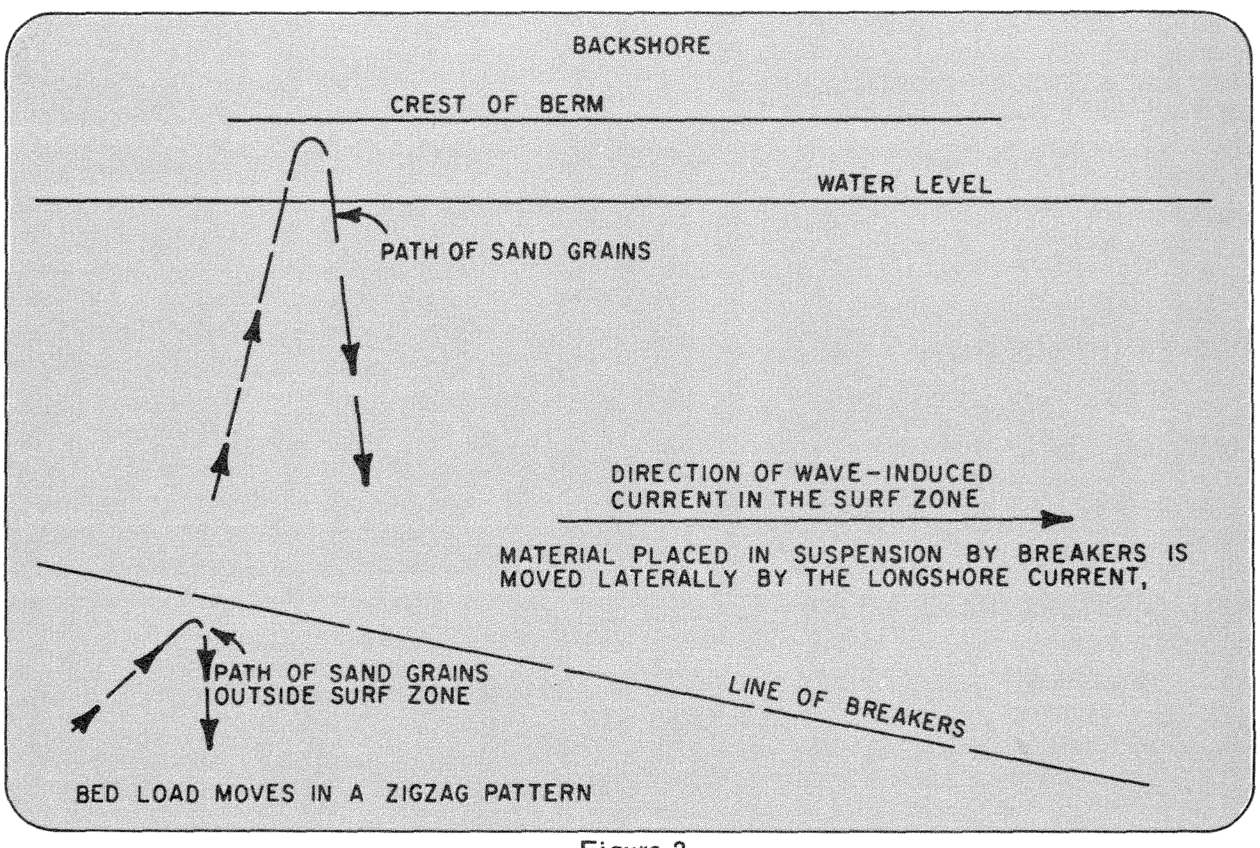


Figure 2

The net rate of littoral transport depends upon the amount of sand available, the shoreline alignment and the direction and energy of the waves. Due to the general alignment of California's coastline and the majority of waves arriving from the North Pacific, littoral transport is generally from north to south. Local conditions such as land promontories and offshore islands may alter this condition.

Little data is available on littoral transport rates except where man has created a trap to stop the sand. Even though a beach may appear to be in a stable state, there may be considerable littoral transport with sand moving in to a reach of coast as fast as it moves out.

Some examples of rates of littoral transport where it has been possible to take measurement over a period of years are Santa Cruz Harbor 300,000 cubic yards, Santa Barbara 300,000 cubic yards, and Port Hueneme 1,200,000 cubic yards annually.

Effect of Submerged Features

As waves approach the shore, they are affected by the shape of the bottom when the depth is equal to one half the wave length. That part of the wave that reaches the shallow depths first tends to slow down while that in deeper water continues at the same speed. This causes the waves to change the direction of approach so that the wave crest in shallow water is more parallel to the beach than it was in deep water. This phenomenon, known as refraction, concentrates wave energy on those features of the coast that extend out into the ocean such as headlands and deltas and reduces the energy in indentations of the coast such as bays, estuaries and submerged valleys. The overall effect is to erode the promontory and fill the low areas so that the coastline gradually becomes straight and more parallel with the attacking wave crests. If the promontories are rocks or boulders, erosion takes place very slowly. Where it consists of sand or other fine material, the erosion occurs rather quickly, noticeably changing the alignment of the beach.

Formation of Deltas

The fresh water from rivers and upland streams flows to the sea, in some cases directly, and in other cases through estuaries, bays or lagoons. Sediments brought down by rivers flowing directly into the ocean are deposited at the river mouth in the form of a delta. Sand in these deltas is placed in suspension by the waves, and is carried onto the beaches toward which the longshore current is moving. In this way, sediments brought down by rivers and streams feed the ocean beaches. During moderate river flow through the estuary, bay or lagoon into the ocean, the river sediment is frequently deposited in the protected area and only the water reaches the ocean.

In such cases, the sand is not supplied to the ocean beaches. However, during an extremely high flow of a river these deposits may be again picked up and swept to the ocean where they are deposited in the delta.

In arid regions such as Southern California where the rivers flow only infrequently, little or no sediments are transported most years. It is only during the rare but intense storms that bring heavy rainfall and flood flows in the rivers that sediments are brought to the beaches. The resulting delta (18 million tons in the Santa Clara River Delta in 1969 flood) gradually erodes under wave action between the flood periods to nourish the adjacent beaches.

Deepwater Canyons

Along the California coast are a number of deepwater canyons that cut through the continental shelf with the head of the canyon reaching very close to shore. If the canyon intercepts the sand moving along the shore, the sediments will flow down the canyon to the ocean depths, never to be recovered. This situation is notably apparent at Moss Landing, Pt. Hueneme, Pt. Mugu, Redondo Beach and La Jolla. Trapping this sand before it reaches the canyon and mechanically transferring it to undernourished beaches may be an answer to some erosion problems.

In some instances the canyon will trap virtually all of the sand moving along the coast. Down drift of such a canyon a new "littoral cell" begins with the sand from each coastal stream contributing to the total longshore movement of sand until another barrier is reached that terminates the process.

Because the energy of a wave is disbursed as the wave travels over a submarine canyon, a harbor at such a location is not subjected to normal wave action and therefore needs less expensive protective structures. The harbors at Moss Landing in Monterey Bay, Pt. Hueneme and Redondo Beach in Southern California have taken advantage of these conditions.

Impact of Storms

Severe storms moving over the ocean near the coast will change beaches drastically. Such storms generate large, steep waves. These waves take sand from the beach and carry it offshore. They move much more sand than do ordinary waves. In addition, the strong winds of the storm often create a storm surge. This surge raises the water level and exposes higher parts of the beach not ordinarily vulnerable to waves. Structures, inadequately protected and located too close to the water, are then subjected to the forces of the waves and may be completely destroyed. Low-lying areas next to the ocean or lagoons and bays may be flooded by such storm surge. Storm surges are especially damaging if they occur at the same time as high tide.

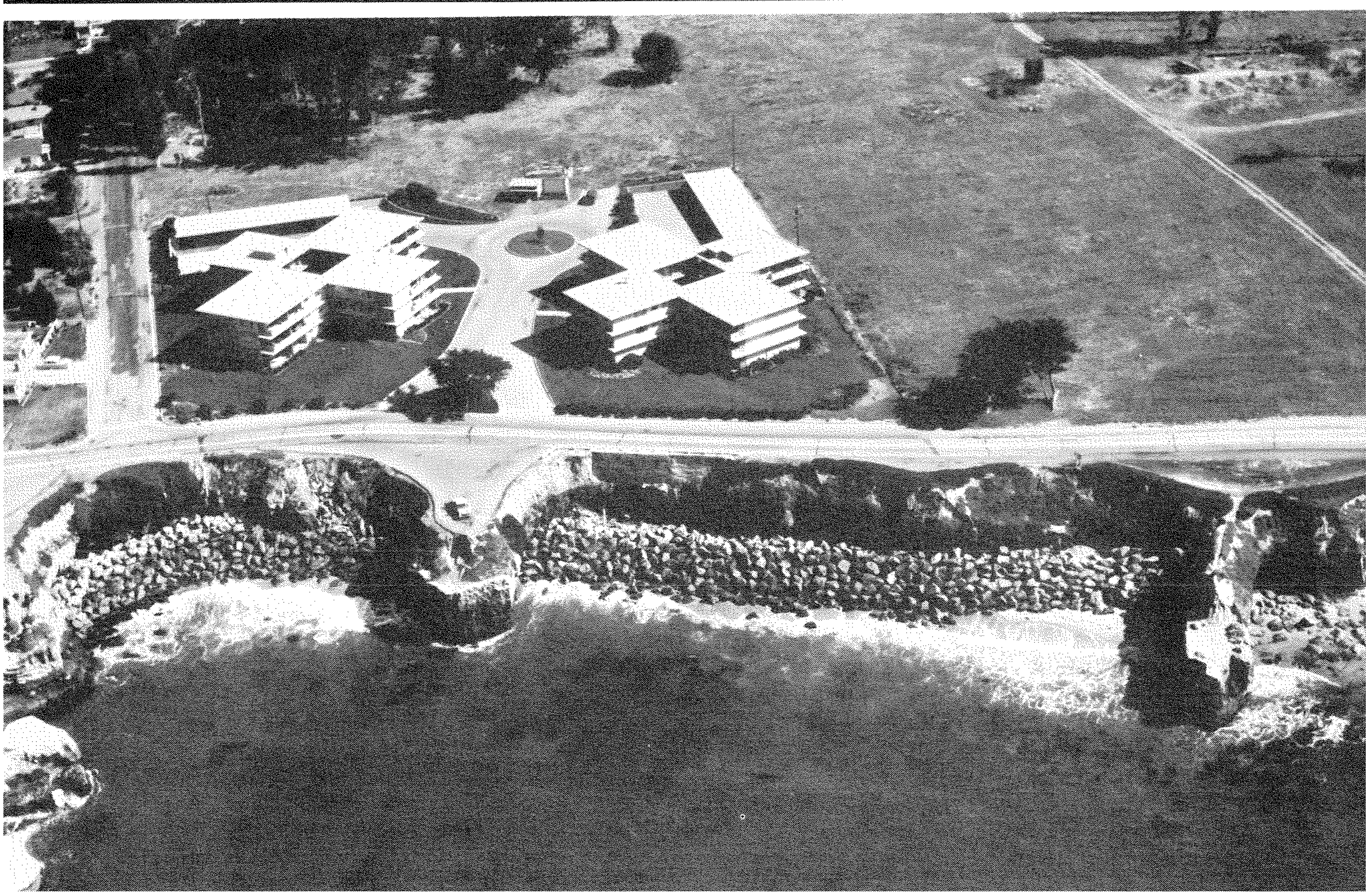
The berm, or berms of the beach are built naturally by waves to an elevation approximately the highest point reached by normal storm waves. While the berms tend to absorb the major forces of the waves, overtopping permits waves to reach the dunes or bluffs in back of the beach and damage unprotected manmade features.

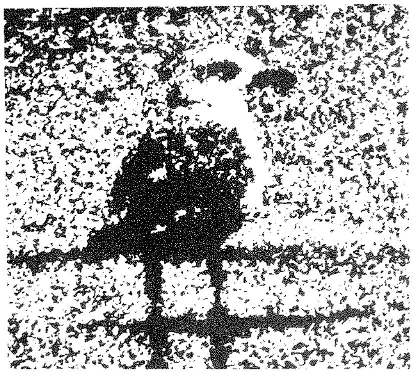
When storm waves erode the berm and carry the sand offshore, the protective value of the berm is reduced and large waves can overtop the beach. The width of the berm at the time of a storm is thus an important factor in the amount of upland damage the storm can inflict.

In spite of the changes in the beach that result from storm-wave attack, a gently sloping beach of adequate width and height is nature's most effective method of dissipating wave energy.

Beach Stability

Although a beach may temporarily be eroded by storm waves and later restored by swells, and erosion and accretion patterns may occur seasonally, the long-range condition of the beach -- whether eroding, stable or accreting -- depends on the rates of supply and loss of littoral material. Erosion or recession of the shore occurs when the rate of loss exceeds the rate of supply. The shore accretes when the rate of supply exceeds the rate of loss. The shore is considered stable (even though subject to storm and seasonal changes) when the rates of supply and loss are equal.





1

Shore Protection Methods

Once established on a section of shoreline and having made considerable investments in structures, roads, utilities, etc., man finds himself in the position of having to make additional investments to protect what he has developed. Where beaches, dunes or rocky cliffs serve to protect the shore developments, additional protective structures may not be required. However, in some localities where development encroaches onto the beach or the edge of eroding bluffs, storm waves overtop the beach and damage backshore structures or cause the bluffs to give way. Measures designed to stabilize the shore fall into two general classes: 1) a structure to prevent waves from reaching erodible materials; and 2) an artificial supply of sand to the shore to make up for a deficiency in sand supply through natural processes, with or without structures such as groins to reduce the rate of loss of littoral material.

2

Comprehensive Protection

Separate protection for short reaches of eroding shores (as an individual lot frontage) within a larger zone of eroding shore, is difficult and costly. Such protection often fails at the flanks as the adjacent unprotected shores continue to recede. Partial or inadequate protective measures may even accelerate erosion of adjacent shores. Coordinated action under a comprehensive plan which considers the erosion processes over the full length of the receding shore segment is much more effective and economical.

3

Bulkheads, Seawalls and Revetments

Protection on the upper part of the beach, fronting backshore development, may be a partial substitute for the natural protection that is lost when the dunes are destroyed. Shorefront owners have resorted to armoring of the shore by wave-resistant walls of various types. A vertical wall in this location is sometimes known as a bulkhead or seawall, and serves as a secondary line of defense in major storms. Bulkheads have been constructed of steel, timber, or concrete piling. For beaches subject to continued erosion, bulkheads do not provide a long-lived permanent solution, because eventually a more substantial wall is required as the beach continues to recede and larger waves reach the structure. While seawalls may protect the upland, they do not hold or protect the beach which is the greatest asset of shorefront property. In some cases, the seawall may be detrimental to the beach in that the downward forces of water, created by the waves on striking the wall, rapidly remove sand from the beach. A stone apron is sometimes used to minimize scouring of the beach and undermining the wall.

A revetment armors the slope face of a bluff with one or more layers of rock or concrete. This protection dissipates wave energy with less damaging effect on the beach than waves striking vertical walls.

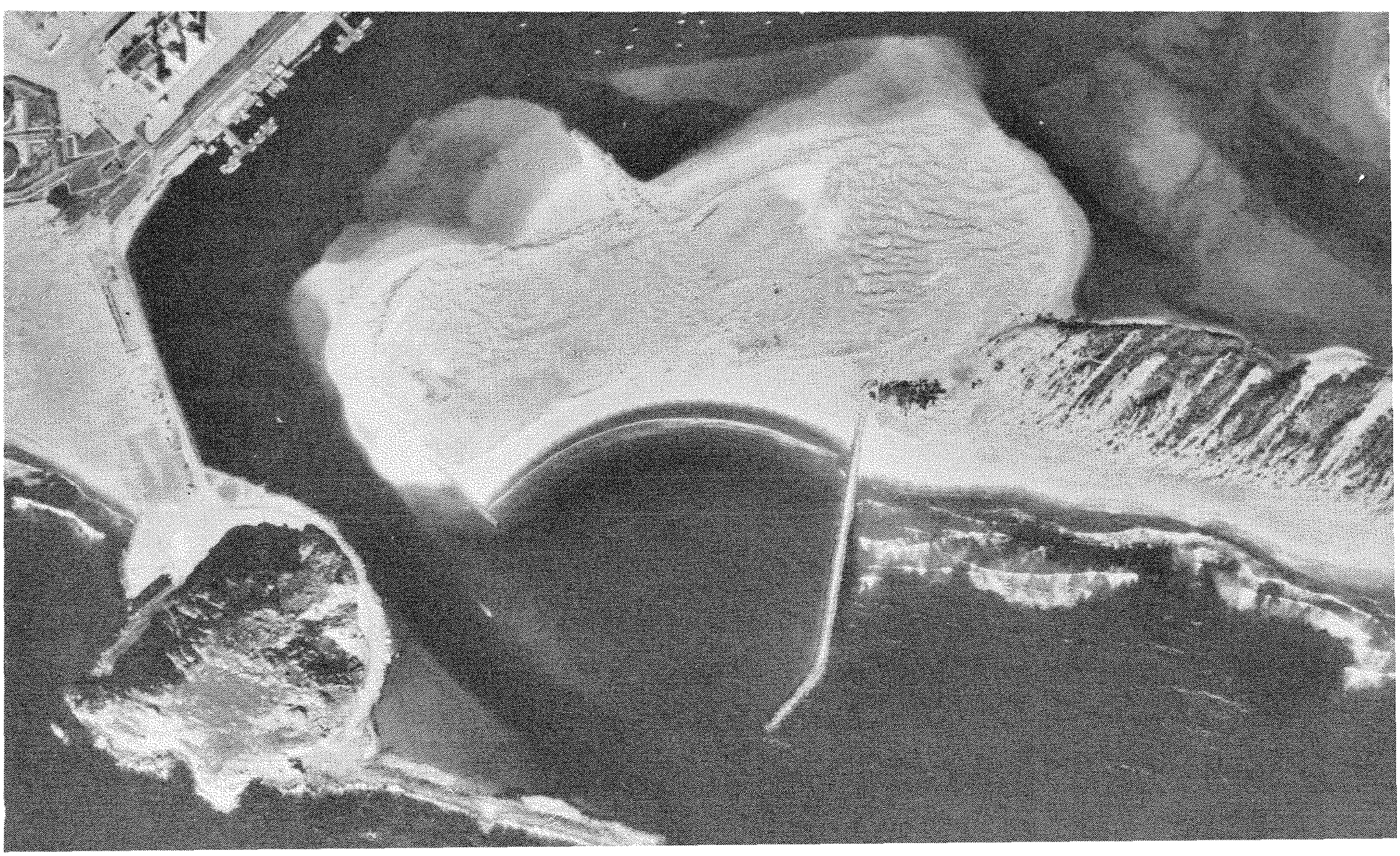
4

Breakwaters

Beaches and bluffs or dunes can be protected by an offshore breakwater that prevents waves from reaching the shore. However, offshore breakwaters are more costly than onshore structures, and are seldom built solely for this purpose. Offshore breakwaters are constructed mainly for navigation purposes. A breakwater enclosing a harbor area provides shelter for boats. Breakwaters have both beneficial and detrimental effects on the shore. All breakwaters reduce or eliminate wave action and thus protect the shore immediately behind them.

Whether offshore or shore-connected, the elimination of wave action reduces littoral transport, obstructing the free flow of sand along the coast and starving the downstream beaches. At a harbor breakwater, the sand flow generally can be restored by pumping the sand through a pipeline from the side where sand accumulates to the starved side. This type of operation has been in use for many years at Santa Barbara.

Even without a shore arm, an offshore breakwater stops wave action and creates a quiet water area between it and the beach. In the absence of wave action to move the sand stream, the sand is deposited and builds the shore seaward toward the breakwater. The buildup actually serves as a barrier and completely dams the sand stream, depriving the downdrift beaches of sand. Although this type of construction is generally detrimental to downstream beaches, there is one case in which it may be used to aid the beach processes. When placed on the updrift side of a navigation opening, the structure impounds sand, prevents it from entering the navigation channel, and affords shelter for a floating dredge to pump the impounded material across the navigation opening back into the stream of sand moving along the shore. This method is used to trap sand at Channel Island Harbor where it is mechanically transferred downcoast past the Pt. Hueneme jetties.



5

Groins

Long ago investigators noted that obstructions on a beach, such as logs or wrecks, would trap sand moving along the beach and cause the beach to widen. Such observations led naturally to devising the groin, a barrier-type structure which extends from the backshore into the littoral zone of sand movement. In earlier times, prior to the current extensive development of upstream river basins and major portions of the seacoast, the natural supply of beach sand was plentiful, and in many instances groins succeeded remarkably well. This led to further, excessive, and indiscriminate use of groins. They often were installed without considering all the factors pertaining to the particular problem. However, this system can somewhat reduce the rate of loss of sand and the rate of shore recession in many instances. The basic purpose of a groin is to interrupt alongshore sand movement to accumulate sand on the shore or to retard sand losses. Trapping of sand by a groin is done at the expense of the adjacent downdrift shore unless the groin or groin system is filled with sand to its entrapment capacity. To reduce the potential for damage to property downdrift of a groin, some limitation must be imposed on the amount of sand permitted to be naturally impounded on the updrift side. Since more and more shores are being protected, and less and less sand is available as natural supply, it is now desirable, and frequently necessary, to place sand artificially to fill the area between the groins, thereby ensuring a more or less uninterrupted sand supply to downdrift shores.

6

Jetties

Another structure developed to modify or control sand movement is the jetty. This structure is generally employed at inlets in connection with navigation improvements. When sand being transported along the coast by waves and currents arrives at an inlet, it flows inward on the flood tide to form an inner bar, and outward on the ebb tide to form an outer bar. Both formations can be hazardous to navigation through the inlet, and must be controlled to maintain an adequate navigation channel. The jetty is similar to the groin in that it dams the sand stream. Jetties are usually constructed of rock, and may be capped with units of concrete armor designed to withstand the wave forces. Their design depends on foundation conditions, wave climate, and economic considerations. Jetties are considerably larger than groins, since jetties sometimes extend from the shoreline seaward to a depth equivalent to the channel depth desired for navigation purposes. To be of maximum aid in maintaining the channel, the jetty must be high enough to completely obstruct the sand stream. Jetties aid navigation by reducing movement of sand into the channel, by stabilizing the location of the channel, and by shielding vessels from waves. Adversely, sand is impounded at the updrift jetty. Prior to the installation of a jetty, nature supplies sand by transporting it across the inlet intermittently along the outer bar to return to the downstream shore.

To eliminate undesirable downdrift erosion, it may be necessary to provide for dredging the sand impounded by the updrift jetty and pumping it through a pipeline. This ensures an uninterrupted flow of sand alongshore to nourish the downdrift beach, and also prevents shoaling of the entrance channel.

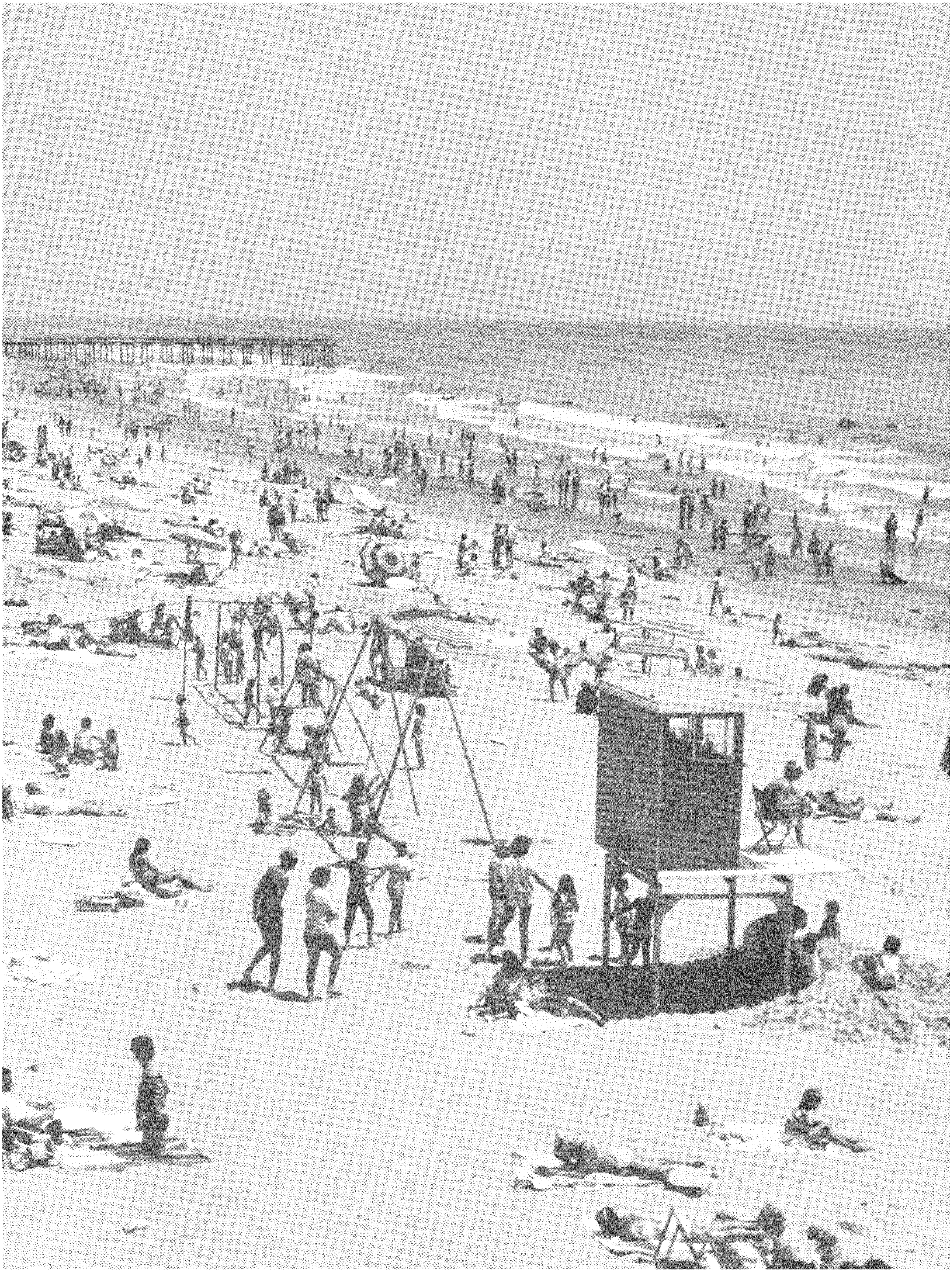
7

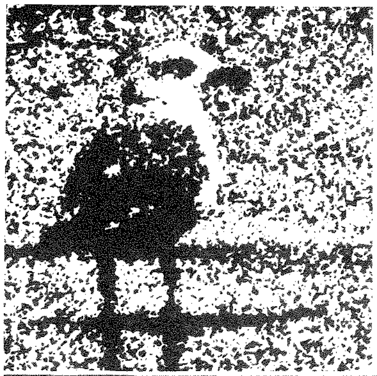
Beach Restoration and Nourishment

Beach structures, when properly used, have a place in shore protection. But research has shown that the best protection is afforded by using methods as similar as possible to natural ones. In other words, a greater degree of effectiveness is obtained by the type of protection provided by nature, which permits the natural processes to continue unhampered. To simulate natural protection, dunes and beaches are rebuilt artificially. Sand from sources behind the beach or offshore is placed on the shore. To ensure continued stability of the beach, material is placed periodically to make up deficiencies in the natural supply. This is most economical for long beaches as the increase of supply benefits the entire beach.

Coastal engineers can now determine required dune and beach dimensions to protect against storms of any given intensity. Beach dimensions, including height and width of berm and characteristics of sand required to maintain beach slopes, can be designed to withstand storms of a specified degree of severity. Sometimes structures must be provided to protect dunes, to maintain a specific beach shape, or to reduce nourishment requirements.

In each case, the cost of such structures must be weighed against the added benefits they would provide. Thus, measures to provide and keep a wider protective and recreational beach for a relatively short section of an eroding shore would require excessive nourishment without supplemental structures such as groins to reduce the rate of loss of material from the widened beach. A long, high terminal groin or jetty is frequently justified at the downdrift end of a beach restoration project to reduce losses of fill into a submerged canyon.





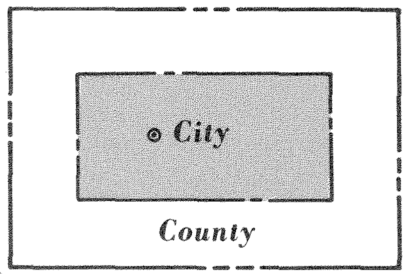
Federal

U.S.Army
Corps of Engineers

State

STATE OF CALIFORNIA
RESOURCES AGENCY
DEPARTMENT OF NAVIGATION AND OCEAN DEVELOPMENT

Local



The Role of California State Government

The State of California has taken steps to insure the best use and orderly development of our shoreline areas as well as their protection and restoration.

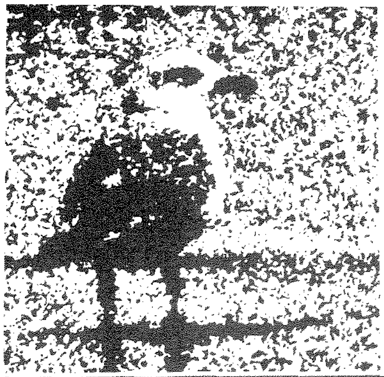
In the 1940's, the responsibility for beach preservation activities within the State was vested with the Division of Beaches and Parks of the Department of Natural Resources. In 1953, these responsibilities were transferred to the Division of Water Resources of the Department of Public Works and its successor agency, the Department of Water Resources. The Governor's Reorganization Plan No. 2 of 1969 transferred the beach erosion control program to the Department of Navigation and Ocean Development.

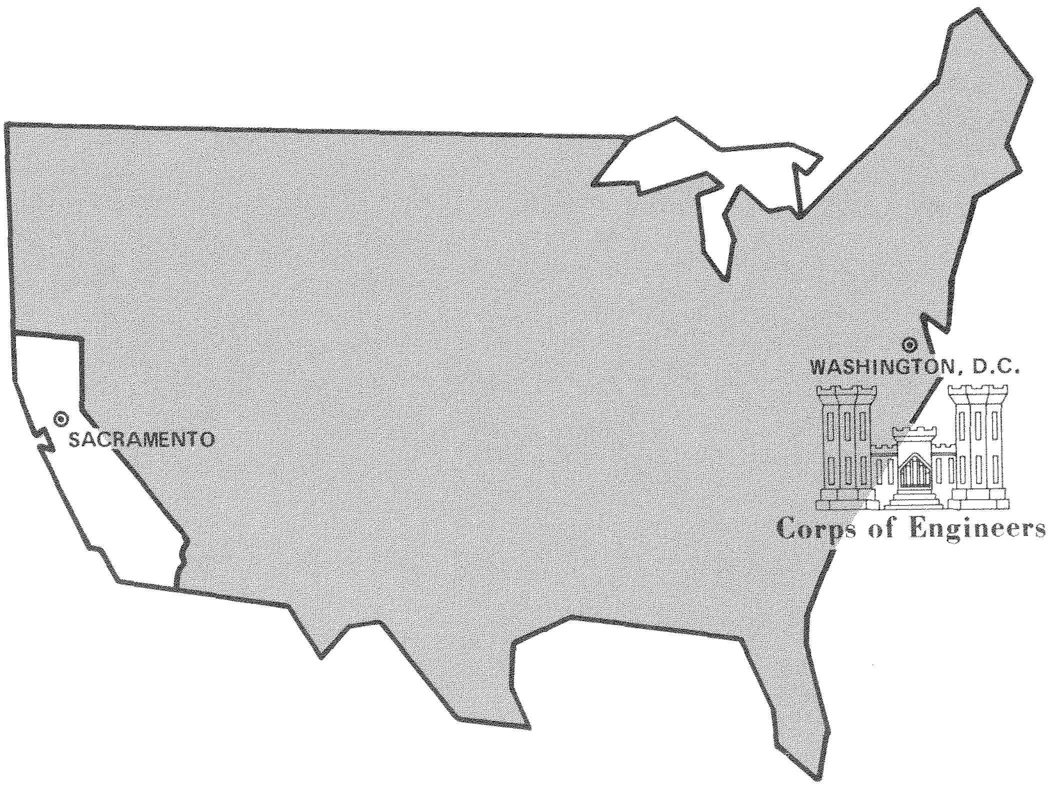
These responsibilities and functions are presently set forth in Sections 65 through 67.3 of the State Harbors and Navigation Code. The statutes authorize the State (1) to study and report upon problems of beach erosion and means for stabilization of beaches and shoreline areas; (2) to prepare plans for and construct such works as its studies and investigations indicate to be necessary; (3) to conduct studies or design and construct projects either by itself or in cooperation with any local or federal agency or any other State agency; and (4) to act as advisors to all agencies of government.

In the development of beach erosion control projects authorized by Congress it is the State's policy to bear one-half the costs of the local participation required by the authorizing federal legislation. The other half of the local participation is borne by the local governmental entity involved or the State agency which controls the property. All State expenditures for the development of a project (planning, design or construction) must be specifically appropriated by the Legislature either in the regular budget bill or by a bill introduced for that particular project. This holds true for either a federal-state project or one developed by the State alone.

A major portion of the State's effort in shore protection has been in the role of advisor to State and local government and acting as liaison between local government and the Corps of Engineers. The State has, however, made investigations and published reports on various aspects of beach erosion and on a few projects as well.

Through the new Sea Grant Program under the National Oceanic and Atmospheric Agency the State has provided funds for research on a dynamic breakwater, inshore processes in littoral zones and new materials for construction in the ocean. This work is being carried out at the Scripps Institution of Oceanography on the San Diego campus of the University of California.





- Research
- Investigation
- Project Design
- Provide Funds
- Construction
- Local Assistance

The Role of Federal Government

Beginning with an act approved July 2, 1930, the U.S. Army Corps of Engineers was authorized to investigate shore processes and beach erosion problems, in cooperation with the states. Later authorizations permitted the federal government to assume up to 50 percent of the construction costs for protecting publicly-owned or publicly-used beaches, up to 70 percent of the construction cost for protecting certain publicly-owned shore parks or conservation areas, and to make limited contribution toward the cost of protecting privately-owned shore areas. Non-federal interest must assume all remaining costs and meet certain other requirements of local cooperation. Investigations of beach erosion and related problems may be carried out entirely at federal expense and must be authorized by River and Harbor Acts or by resolutions of the Senate or House Committee on Public Works. Except for small projects which may be authorized by the Chief of Engineers, federal participation in beach erosion control and shore protection projects must be specifically authorized by Congress.

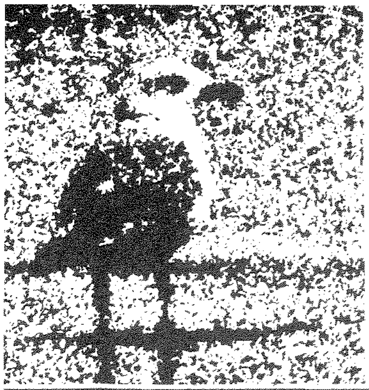
Under provisions of Section 103 of the River and Harbor Act of 1962, the Corps may construct certain small beach erosion control projects without specific authorization by Congress. These projects are subject to the same requirements of feasibility and economic justification as projects requiring Congressional authorization. However, the number of small beach erosion control projects is limited by the availability of funds. The national allotment for small beach erosion control projects does not exceed $25,000,000 for any one year, and not more than $1,000,000 may be allotted for the construction of a single project. Each small beach erosion control project must be complete in itself and not commit the Federal Government to additional improvement to insure effective operation.

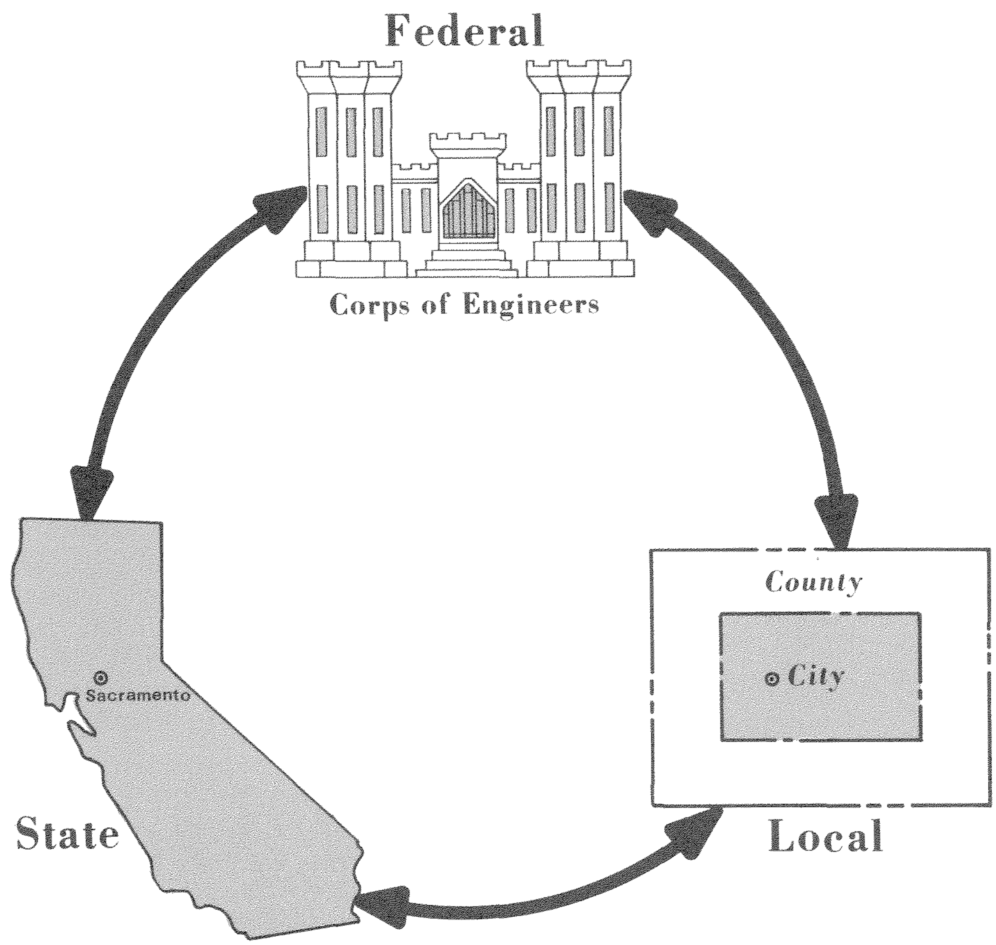
The River and Harbor Act of 1968 authorizes the Corps to make an appraisal investigation and study, including a review of previous studies and reports, of erosion along the Pacific Coast as well as along other coastal areas of the United States. It also authorizes the Corps to investigate, study and construct projects for the prevention or mitigation of shore damages attributable to federal navigation works.

The U. S. Army Corps of Engineers researches the causes of beach erosion, investigates and studies specific beach erosion problems, and constructs -- or, in certain cases, reimburses local and State governments for constructing -- shore protection and beach restoration projects.

In the early 1930's the Army Corps of Engineers began investigations of the various forces at work along coasts and shores. Today, the Coastal Engineering Research Center (CERC) is deeply involved in investigations of shore processes, storm frequencies, and stormtide elevations. Research into remedial measures is accomplished at CERC by its engineers and scientists; in addition, many significant programs are carried out by universities and private research organizations under contracts with CERC.

Without research, the effectiveness of completed projects might be uncertain, and costly overdesign or failure might be common. However, shore protection programs are the "payoff" in terms of preservation of natural beaches and recreational areas as well as the protection of life and property.




Federal
Corps of Engineers
State
Sacramento
Local
County
City

Federal-State-Local Cooperative Projects

The State has participated in the development of virtually all of the beach erosion control projects undertaken by the Federal Government in California. Table 1 provides a summary of those projects and the estimated total first costs. Table 2 sets forth the State's expenditures for those projects on a fiscal year basis. It is anticipated that more than $54,000,000 worth of shore protection and recreational benefits will accrue to the people of the State for the $3,259,000 State investment in these projects.

The procedures necessary to bring a federally-funded beach erosion control project from conception to completion are lengthy and complex, taking from 10 to 12 years. The local sponsor, through its congressman, must get approval from the Public Works Committee to have an investigation made by the Corps of Engineers which requires funding by Congress. The Corps of Engineers will then hold hearings, make studies on various designs and their impact on the environment along with costs and benefits and prepare a report. This report is reviewed by a number of levels within the Corps, other federal agencies which may be involved, local and State Government and if approved, is sent to Congress and the Bureau of the Budget. If it receives Congressional approval, it then becomes an authorized project. It then is necessary to have local and State Government provide assurances to fund the local share and have the project included in a Congressional appropriation bill, passed upon by various committees, Congress, and ultimately signed by the President.

The project can then be planned in detail by the Corps, and when local and State funds are made available, the project is put out for bid.

Both local and State Governments must follow a similar but perhaps simpler procedure on authorization and appropriation for their share of the project. Although little investigation and detail project planning is required on their part, they must provide the land easements and rights-of-way for the project and of course review the project plans to be assured that it is not in conflict with other local plans and be in conformance with their own policies.

Small beach erosion projects which come under Section 103 of the Rivers and Harbors Act can be constructed without specific authorization from Congress or the State Legislature. Congress appropriates $25,000,000 each year for this type of project. They must receive a specific appropriation from the State Legislature however. The hearing, design review, and construction processes are virtually the same as the larger projects but the time required to complete the process is somewhat less. The requirements on local government for providing land easements and rights-of-way and obtaining the necessary approvals from control agencies are about the same on either type of project.

Table 1

BEACH EROSION CONTROL PROJECTS COMPLETED

County Name of Project	Completion Date	Total First Cost	Scope of Project
Santa Cruz County			
City of Santa Cruz	1964	$ 552,000	Riprap seawall
City of Capitola	1963	$ 74,000	Riprap seawall
City of Capitola 1/	1970	$ 146,100	1 groin and sand fill
Ventura County			
Pierpont Bay	1967	$2,157,000	7 groins & sand fill replenishment
Pierpont Bay	1973	$ 370,000	1 groin & sand replenishment
Los Angeles County			
Cabrillo Beach	1962	$ 392,000	1 groin
Redondo Beach	1970	$2,400,000	Groin & sand replenishment
Orange County			
Seal Beach	1960	$ 286,000	Groin & sand fill
Doheny Beach (Stage 1)	1964	$ 247,000	Groin & sand fill
Doheny Beach (Stage 2)	1966	$ 713,000	Sand replenishment
Doheny Beach (Rehab.)	1968	$ 40,000	Rehabilitate groin
Anaheim Bay to Newport Bay (Stage 1)	1964	$1,910,000	Sand replenishment
Anaheim Bay to Newport Bay (Stage 2)	1968	$ 700,000	2 groins & sand replenishment at Newport
Anaheim Bay to Newport Bay (Stage 3)	1970	$ 600,000	4 groins & sand replenishment at Newport
Anaheim Bay to Newport Bay (Stage 4a)	1971	$1,074,000	Sand replenishment at Surfside
Anaheim Bay to Newport Bay (Stage 4b)	1973	$ 426,000	Rehabilitate 2 groins & add 1
Anaheim Bay to Newport Bay (Stage 5)	1973	$1,100,000	3 groins & sand replenishment at Newport
San Diego County			
Ocean Beach	1955	$ 161,000	Groin & sand fill
Imperial Beach (Stage 1)	1959	$ 66,000	Groin
Imperial Beach (Stage 2)	1961	$ 60,000	Groin
Imperial Beach (Stage 3)	1963	$ 55,000	Extension of groin
Oceanside Beach	1963	$1,785,000	Groin & sand replenishment
Bird Rock	1966	$ 101,000	1,300 feet of riprap seawall
Sunset Cliffs (Segment B)	1971	$ 320,000	Rubblemound walls along cliffs
Sunset Cliffs (Alternatives)	1973	$ 50,000	Additional walls

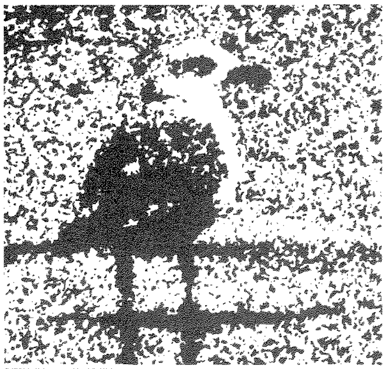
1/ Joint City of Capitola - Department of Parks & Recreation project.

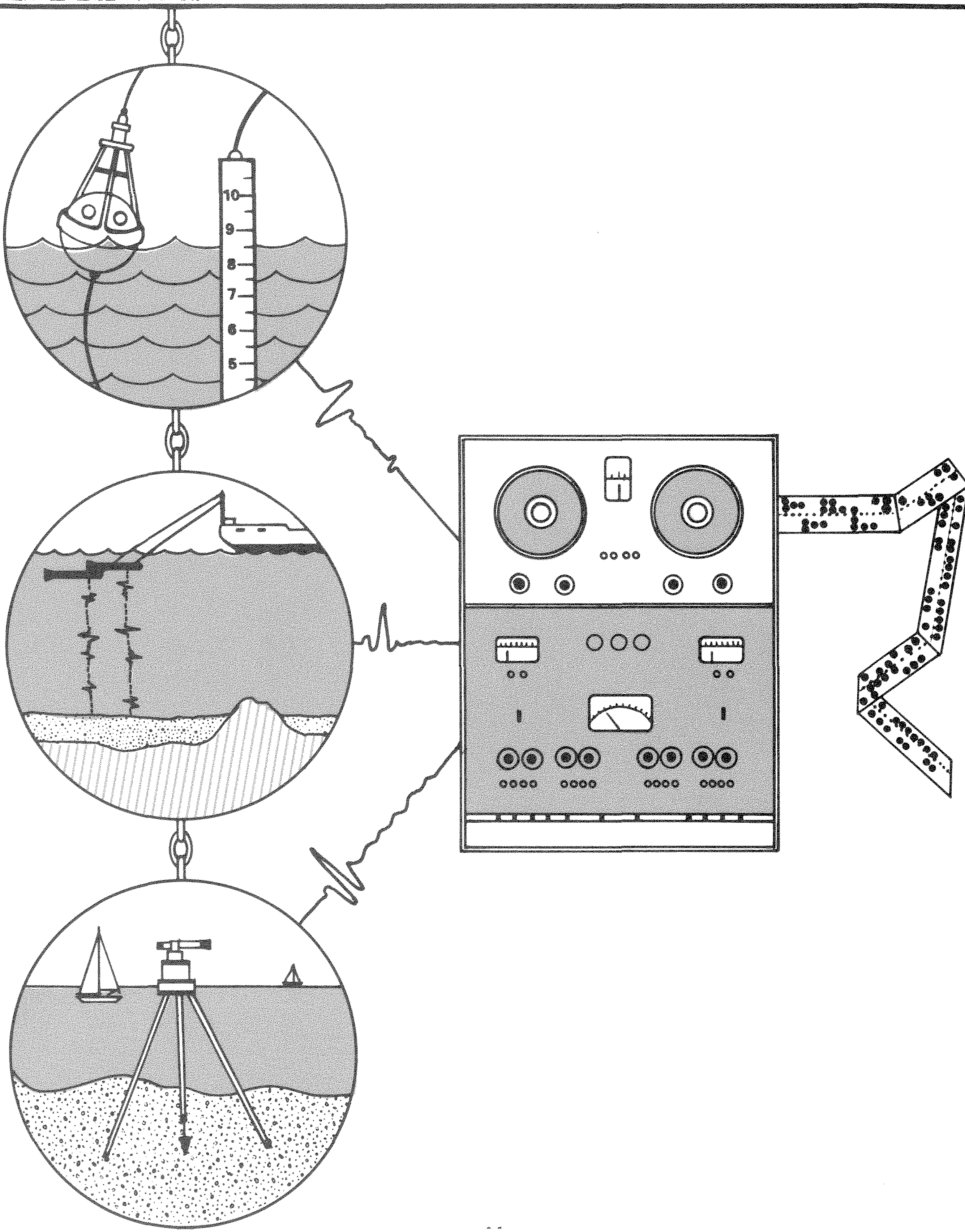
Table 2

BEACH EROSION CONTROL PROJECTS
STATE EXPENDITURES BY YEAR
(Thousands of Dollars)

COUNTY / Fiscal Year	59-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71	71-72	72-73	Project Total	County Total
San Diego County																182
Imperial Beach	20	15			11										46	
Oceanside				30											30	
La Jolla								13							13	
Sunset Cliffs												80		13	93	
Orange County																1,738
Seal Beach	95														95	
Doheny					106		326								432	
Newport					481				156		134	95	71	274	1,211	
Los Angeles County																619
Cabrillo Beach				98											98	
Redondo Beach										440		81			521	
Ventura County																547
Ventura-Pierpont				133		97		317							547	
Santa Cruz																186
Santa Cruz					186										186	
	115	15		261	784	97	326	330	156	440	134	256	71	287	3,272	3,272

1. Actual expenditures where available (to nearest $1,000).
2. Figures given after 1972 are estimated pending final counting by Corps of Engineers.
3. Figures include funds contributed by Parks and Recreation when acting as local sponsor.
4. Expenditures are assumed to occur in the fiscal year in which project, or project stage, was completed.

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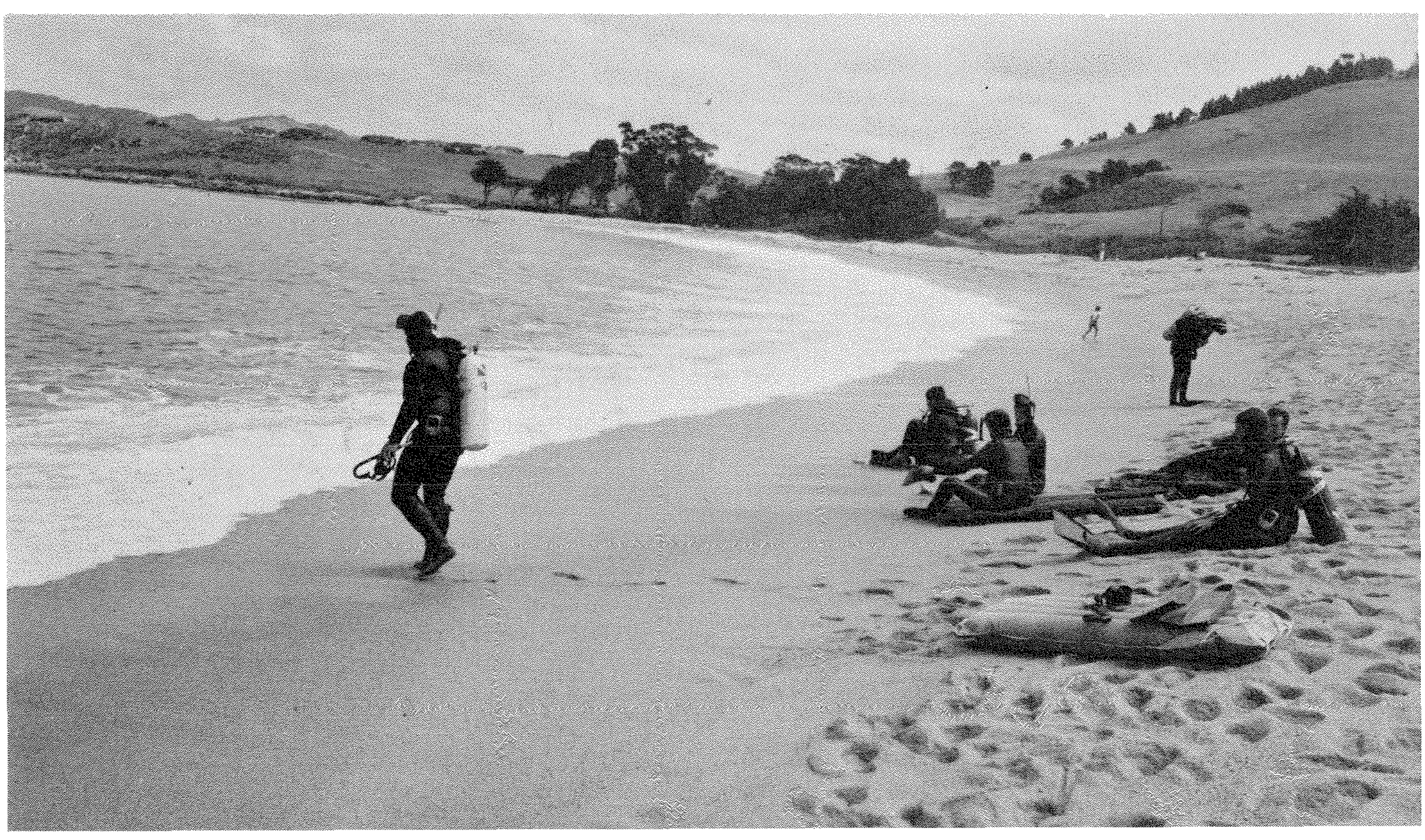
State–Federal Data Collection and Studies

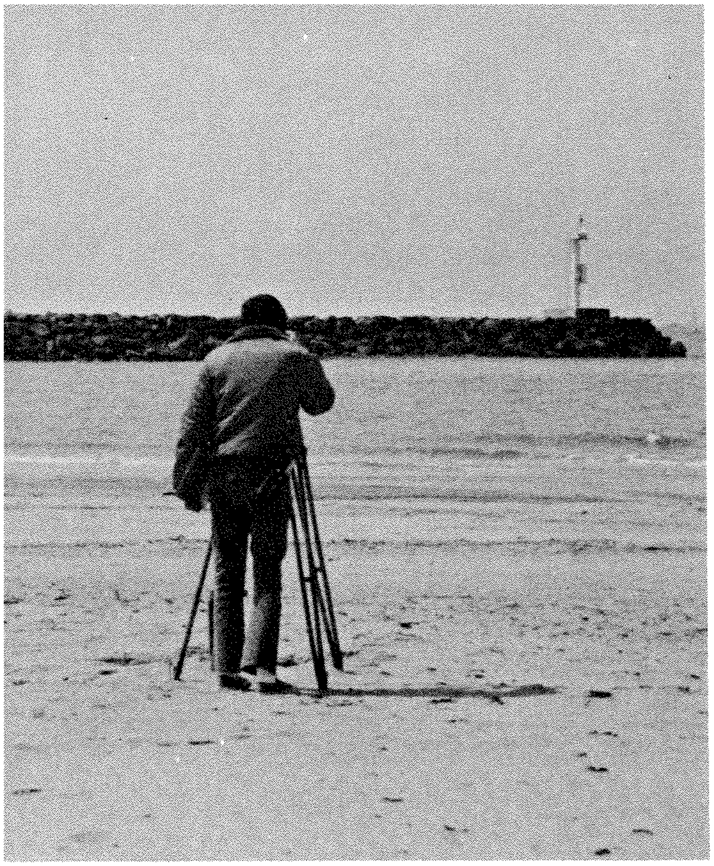
Since 1960, the State and federal governments have been involved in a continuous program of data collection in the area of the coastline from Cape San Martin, in Monterey County, to the Mexican border. In addition, there has been a similar study conducted in certain areas of Northern California between 1959 and 1972. The scope of these studies has decreased during the past two fiscal years due to budget limitations.

This cooperative effort, funded on a 50-50 basis between the State and federal governments but carried on by the Corps, includes obtaining aerial and ground photographs, collecting and analyzing beach and offshore sand samples, conducting shoreline and hydrographic surveys, installing and maintaining wave gages, conducting research on littoral sand movement, sand bypassing, offshore sand supplies, and the effect of submarine canyons on littoral drift.

A Littoral Environment Observation project (LEO) along the California coastline has been coordinated by the Department of Navigation and Ocean Development and carried on under the guidance of the Coastal Engineering Research Center (CERC) of the U. S. Army Corps of Engineers, Washington, D.C. The California Department of Parks and Recreation and the Department of Transportation assisted in collecting data, as well as several other agencies and individual observers.

The data collected consists of: wave period, direction and height, wind velocity and direction, beach slope and width, littoral current velocity and directions, and tide level at time of observation. These data were recorded on IBM data sheets and forwarded to CERC for processing, tabulation and analysis. The analysis will be useful in developing plans for protection of local beaches.

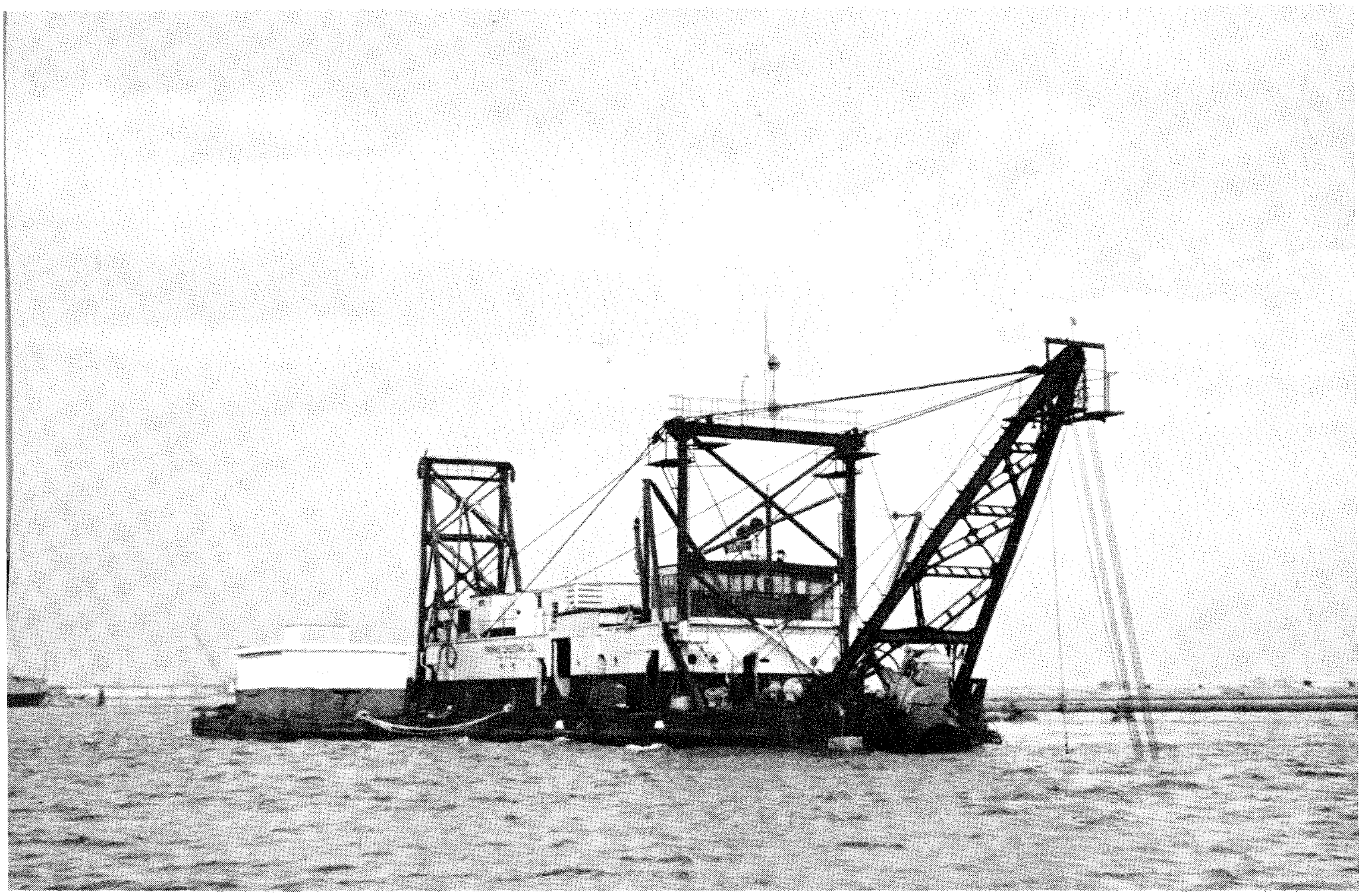


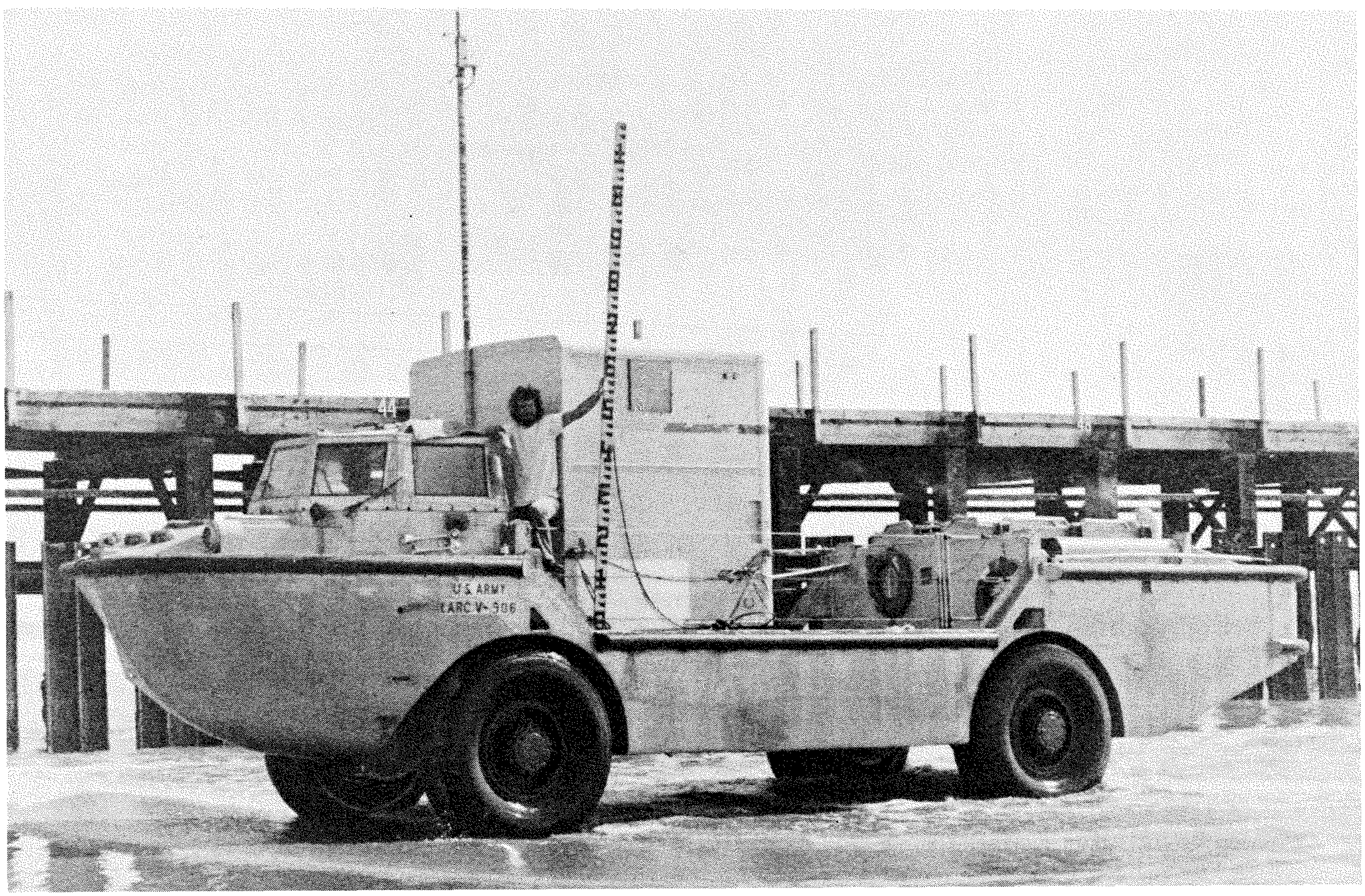


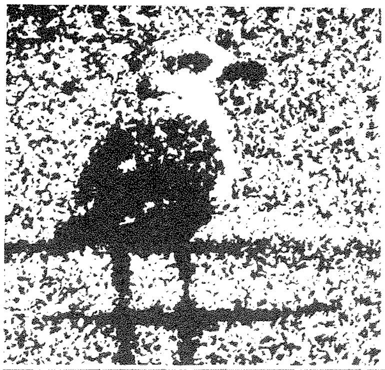
A breakthrough in the use of offshore sand deposits to supply the eroding beaches was made during the pre-project planning phase of the constructed beach fill at Redondo Beach. It was determined that the most economical sand source was directly offshore from Redondo Beach, instead of conventional land source sand deposits. This source of supply is being given consideration in all future beach erosion control projects that require great volumes of sandy beach material. Surveys indicate that large quantities of sand are available offshore in Santa Monica Bay. The grain size make-up of the sand to restore a beach must be compatible with sand on the existing beach if the original beach characteristics are to be maintained. Most sands which have been located offshore are too fine to meet the nourishment requirements.

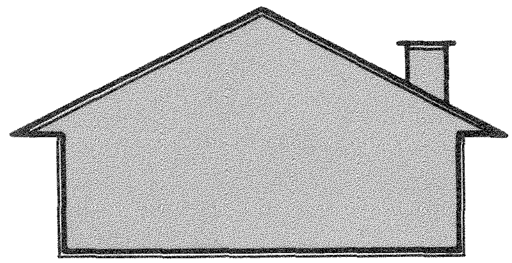
A Perched Beach Study, funded by the Department of Transportation, has been terminated after considerable study by the Corps of Engineers including a number of model studies. The initial purpose was to investigate the possibility of constructing Highway 101 on an earth fill in the ocean north of Santa Monica without adversely upsetting the natural beach processes. The concept involved the creation of a beach along the top of a man-made fill in deep water that would allow sand to be transported by the littoral currents in a manner similar to that occurring in nature. Although a much better understanding of a perched beach has been gained by the study, it was terminated before completion because the Highway Commission abandoned the route of the highway in that location. Throughout the investigation, the Department of Navigation and Ocean Development participated in the discussions and administered the contracts between the State and Federal Government.

The State joined with the Atomic Energy Commission, the United States Army (CERC), and other federal agencies in conducting a radioactive sand tracer study (RIST) in Santa Barbara County and at Oceanside Harbor. Its purpose was to perfect a better understanding of the natural forces shaping our shoreline.

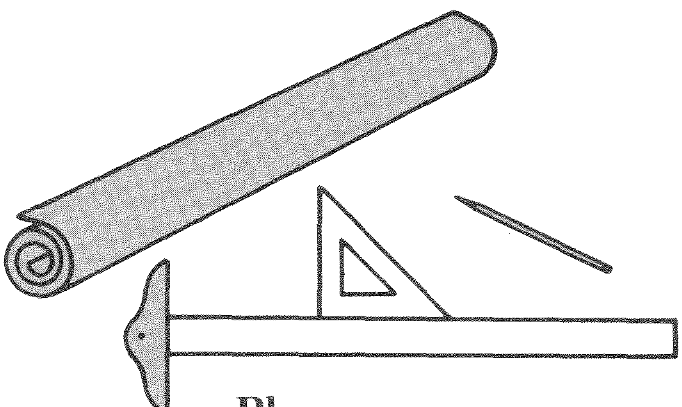



U.S. ARMY

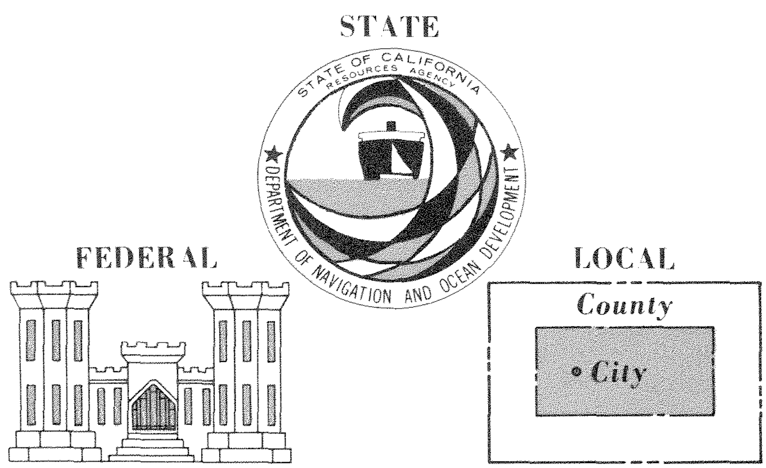




Individual



Planner



Government Agencies

What You Can Do

Whether you are an individual with property endangered by erosion, a planner faced with developing a shoreline project, or a governmental agency responsible for the public beach, what can you do to stop or prevent shoreline erosion? Of course, each situation is unique and requires a particular method to solve the problem. Nevertheless, there are certain general actions that will start you in the right direction.

PREVENTING
AN EROSION PROBLEM

1

Gather all the information possible on the history of shoreline movement in the immediate and adjacent area. What has happened in the past will probably happen again and you must be prepared for it.

2

Seek out others with basic or related objectives of shoreline protection. They may already have some answers to questions that arise in your planning or you may find increased mutual benefits by combining your individual efforts.

3

Provide the ocean the room it wants to advance and retreat. Wave forces are tremendous and it is probably not economically practical to try and oppose them.

4

Before you plan any modifications to the shoreline or make an investment in the proximity, get some expert advice from individuals familiar with shoreline erosion problems. What is intended for protection may only aggravate the problem for you or transfer the problem to the neighboring shoreline.

5

Investigate what others are planning that may have an effect upon your objectives and be alert to new proposals. A potential cause of erosion may be beyond your immediate sphere of responsibility or authority but if instituted, may cause you damage.

6

Most of all, try to work with the ocean, not in opposition. After all, the odds and time are on her side. You may infringe upon her prerogatives when she is in a good mood, but beware if she becomes angry.

CORRECTING
AN
EROSION
PROBLEM

1

First of all, gather all the facts, data, pictures and history of the shoreline in question. Nearby residents may remember useful information, the local public works department may have records from old surveys, state or federal agencies may have aerial photographs. Whatever information you can find on historical movements of the shoreline is useful.

2

Check with adjacent shoreline property owners; they may also be having problems. There is strength in numbers to pool resources for information or ideas. One large project to solve a number of individual problems is usually easier to develop and more economical to build than a series of small ones.

3

Sound out the attitudes of those concerned with the quality of the environment both in the government and in the private sector. The ultimate type of solution for your problem should incorporate their goals as well as yours. Their early support will be helpful later on.

4

Obtain some expert advice from individuals familiar with shoreline erosion problems. State and federal agencies responsible for shore protection programs and consultants working in the coastal engineering field have experts on their staffs that can provide advice based upon the latest techniques and long experience.

5

Solicit help from your governmental representative if you hope to obtain financial assistance through governmental programs. He will be the one to represent you in obtaining an appropriation of funds. If he becomes familiar with your problems at the beginning of project formulation, he can better represent your case at budget time.

6

Finally, don't get discouraged or be impatient. Remember, it has taken nature eons of time to form the shore. It takes the governmental process time to formulate an end product. You should, however, be as persistent as the tireless ocean if you expect to win the race against her.